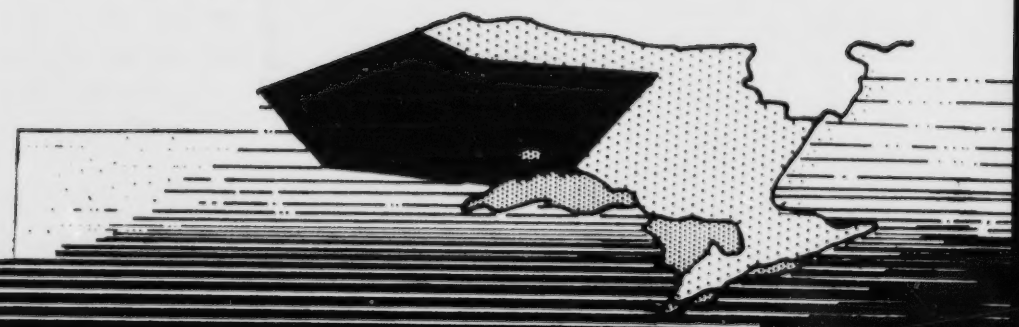
[redacted]



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NORTHWESTERN ONTARIO FOREST
TECHNOLOGY DEVELOPMENT UNIT

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# GROWTH AND YIELD OF NORTHWESTERN ONTARIO BOREAL (CONIFEROUS) FOREST SPECIES: AN ANNOTATED BIBLIOGRAPHY

by

W. Bell, C.J. Hanmore, and A.J. Willcocks

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# GROWTH AND YIELD OF NORTHWESTERN ONTARIO BOREAL (CONIFEROUS) FOREST SPECIES: AN ANNOTATED BIBLIOGRAPHY

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Northwestern Ontario Forest
Technology Development Unit

in cooperation with

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## ABSTRACT

Bell, W.; Hanmore, C.J. and Willcocks, A.J. 1989. Growth and Yield of Northwestern Ontario Boreal (Coniferous) Forest Species: An Annotated Bibliography. Northwest. Ont. For. Tech. Dev. Unit, OMNR, Thunder Bay, ON; Tech. Rep. No. 31. (Unpublished).

Key Words: growth and yield, conifers, bibliography

Presents an annotated bibliography for growth and yield of Northwestern Ontario Boreal Forests. The literature search concentrated on the following five main coniferous species: jack pine (Pinus banksiana Lamb.), lodgepole pine (Pinus contorta Dougl.), red pine (Pinus resinosa Ait.), black spruce (Picea mariana (Mill.) B.S.P.), and white spruce (Picea glauca (Moench) Voss). However, articles pertaining to species related to Northwestern Ontario Boreal conifers are also included herein.

Of the 14 subject areas presented in this report, the main emphasis was placed on growth and development, spacing, thinning, fertilization, and wood quality.

The bibliographies are arranged in alphabetical order by author. Indices are presented by: i) author (alphabetically), and ii) key species and subject. Four hundred and four complete citations and abstracts are presented.

# TABLE OF CONTENTS


| | PAGE |
|---|---|
| ABSTRACT | i |
| ACKNOWLEDGEMENTS | iii |
| INTRODUCTION | 1 |
| KEY TO SUBJECT DIVISIONS | 3 |
| AUTHOR INDEX | 4 |
| SPECIES/SUBJECT INDEX | 16 |
| ANNOTATED BIBLIOGRAPHY | 36 |
| APPENDICES | 202 |
| List of Forest Tree Species | 203 |
| List of Pathological/Entomological Terms | 205 |
| Machine-Readable Cataloging (MARC) Library of Congress Publication Code for Provinces, States & Countries | 206 |
| Metric Units and Their Canadian Yard/Pound Equivalents | 207 |
| Concentrations Used in Soil and Fertilizer Prescriptions | 210 |
| Miscellaneous Technical Abbreviations | 211 |

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## INTRODUCTION

R. Rausher[1] of the USDA Forest Service in his paper "Increasing scientific productivity through better knowledge management" considered management of technology to be one of the major impediments to improvement of the applications of both forestry and agriculture. In many cases the "wheel" has already been invented by scientists and foresters but yet the technology is not being applied at the ground level and in some instances efforts are being duplicated.

In the area of growth and yield, how many times have foresters said "there is no information available" thus preventing improvements in crop planning and/or timber yield predictions. Recent surveys by the Northwestern Ontario Forest Technology Development Unit of their forestry clients indicate that "knowledge of growth and yield of forests" is one of their most important information priorities.

This report lists 404 complete citations and abstracts of growth and yield related publications. The information herein far from represents a state of perfect knowledge for growth and yield, but it does provide the reader with a reasonable idea of what is known to date. This is critical to know if researchers and foresters are to be protected from "reinventing the wheel".

The bibliographies are arranged alphabetically by author. For convenience, indices are included by: i) author (alphabetically), and ii) key species and subject. Of 47 species reported herein, the 5 key species are; jack pine, lodgepole pine, red pine, black spruce and white spruce. The 14 subject areas include; growth and development, spacing, thinning, fertilization, wood quality, and general information. The emphasis is on the growth and development of coniferous species of Northwestern Ontario Boreal Forests.

Included in the appendices are: i) a List of Forest Tree Species, ii) a List of Pathological/Entomological Terms, iii) MARC Country of Publication Code Abbreviations, iv) a Table of Metric Units and Their Canadian Yard/Pound Equivalents, v) a Table of Concentrations Used in Soil and Fertilizer Prescriptions, and vi) a List of Miscellaneous Technical Abbreviations.

All of the publications are available on loan from the Northern Forest Research Unit library in Thunder Bay. In addition to these, other forestry publications may be researched by a computerized library reference called "Pro-Cite". At present, Pro-Cite contains approximately 9,500 entries and access is available through the Northwestern Ontario Forest Technology Development Unit or the Northern Forest Research Unit. Readers are encouraged to obtain the Pro-Cite computerized library database management package.

[1]Rausher, M.H. 1987. Increasing scientific productivity through better knowledge management. AI Applications 1(2): 21-31.

KEY TO SUBJECT DIVISIONS

and

AUTHOR INDEX

## Key to Subject Divisions

| Code | Subject |
|---|---|
| A | Biomass |
| B | Fertilization |
| C | Genetics |
| D | Growth and Development |
| E | Modelling |
| F | Pruning |
| G | Sampling and Data Analysis |
| H | Site Index |
| I | Spacing |
| J | Thinning and Release Cutting |
| K | Volume and Yield Tables and Equations |
| L | Wood Quality |
| M | Other |
| N | Herbicides |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Aaltonen, V.T.(1926) | D, I | NON | 36 |
| Ackerman, R.F.(1962) | D, K | LPP | 36 |
| Agee, J.K. and Biswell, H.H.(1970) | J, B | PP | 36 |
| Alban, D.H.(1978) | D | PR, PJ | 37 |
| Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) | B, A | PJ, PR, SW, TA | 37 |
| Alban, D.H. and Watt, R.F.(1981) | B, D | SB | 37 |
| Alemdag, I.S.(1988) | K | PR, SM | 38 |
| Alemdag, I.S.(1984) | L | NON | 38 |
| Alemdag, I.S.(1982) | A | PJ, SB, SW, BF | 38 |
| Alemdag, I.S. and Stiell, W.M.(1982) | A, I | PR | 39 |
| Alexander, R.R.(1965) | J | LPP | 39 |
| Alexander, R.R.(1960) | J, D | LPP | 39 |
| Alexander, R.R.(1956) | J, D | LPP | 40 |
| Alexander, R.R. and Edminster, C.B.(1981) | K, J | LPP | 40 |
| Alexander, R.R.; Lotan, J.E.; Larson, J.M. and Volland, A.L.(n.d.) | C | LPP | 40 |
| Allison, J.H.(1952) | D, K | PJ | 40 |
| Alm, A.A.; Pflager, S.M. and Schantz-Hansen, R.(1979) | J | PJ | 41 |
| Alm, A.A. and Schantz-Hansen, R.(1970) | J | PJ | 41 |
| Althen, F.W. von; Stiell, W.M. and Forster, R.B.(1978) | J | PR | 41 |
| Anderson, E.A.(1951) | C | WF, NF, DF | 42 |
| Andison, D.; Roebbelen, P. and Beckwith, A.F.(1984) | J | PW, PR | 42 |
| Anon.(1982) | B, I | DF, LPP, WHE | 43 |
| Anon.(1982) | B, I, J | LPP | 43 |
| Anon.(1968) | L, D | SB | 43 |
| Armson, K.A.(1975) | B | PJ | 44 |
| Armson, K.A.(1973) | B | NON | 44 |
| Armson, K.A.(1972) | B, G | PJ, BF | 45 |
| Armson, K.A.(1968) | I, B, J, N | NON | 45 |
| Armson, K.A.(1967) | B | NON | 46 |
| Armson, K.A.(1966) | B, D | SW | 46 |
| Arney, J.D.(1985) | E, D, K | DF | 46 |
| Arney, J.D.(1985) | E | DF | 47 |
| Arnup, R.W.(1987) | J, K, I | SW | 47 |
| Axelsson, R. and Routledge, H.(1970) | I, J | NON | 47 |
| Baker, G.(1967) | K, L | PR | 48 |
| Ballard, L.A. and Long, J.N.(1988) | D | LPP | 48 |
| Barrett, J.D. and Kellogg, R.M.(1986) | C, L | DF | 48 |
| Barse, R.G. and Laidly, P.R.(1980) | L | PR | 49 |
| Bazeley, D.G.(1988) | D, L | PR | 49 |
| Behre, C.E.(n.d.) | D | SR, SW | 49 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Bella, I.E.(1986) | I, K | PJ, PR, SW | 50 |
| Bella, I.E.(1985) | J | PJ, LPP | 50 |
| Bella, I.E.(1974) | D, J | PJ | 51 |
| Bella, I.E.(1974) | J, K | LPP | 51 |
| Bella, I.E.(1972) | J | LPP | 51 |
| Bella, I.E.(1971) | K | DF, PJ, TA | 52 |
| Bella, I.E.(1968) | K | PJ | 52 |
| Bella, I.E.(1967) | J, K, D | PJ, PS | 52 |
| Bella, I.E.(1966) | J, D | PJ | 53 |
| Bella, I.E. and DeFrancheschi, J.P.(1982) | J | LP | 53 |
| Bella, I.E. and DeFrancheschi, J.P.(1980) | I | PJ, PR | 54 |
| Bella, I.E. and DeFrancheschi, J.P.(1977) | J | LPP | 54 |
| Bella, I.E. and DeFrancheschi, J.P.(1974) | J, L | PJ | 55 |
| Bella, I.E. and DeFrancheschi, J.P.(1974) | I | PJ, PR, SW | 55 |
| Bella, I.E. and DeFrancheschi, J.P.(1974) | D, J | PJ | 56 |
| Bendtsen, B.A.(1978) | C, L, B | NON | 56 |
| Bennett, W.(1986) | C, L | NON | 56 |
| Benson, J.A.(1973) | D, K, H | SB | 57 |
| Benson, R.E. and Strong, R.A.(1977) | D | LPP | 57 |
| Benzie, J.W.(1977) | D, K | PJ | 57 |
| Bernier, B.; Brazeau, M. and Winget, C.H.(1972) | B | BF | 57 |
| Berry, A.B.(1986) | K | SW | 58 |
| Berry, A.B.(1984) | A, K | PR | 58 |
| Berry, A.B.(1978) | H, K | SW | 58 |
| Berry, A.B.(1969) | I, D, J | PR | 58 |
| Berry, A.B.(1969) | J, I | PR | 59 |
| Bickford, C.A.(1957) | K | NON | 59 |
| Biltonen, F.E.; Hillstrom, W.A.; Steinhilb, H.M. and Godman, R.M.(1979) | K, L | NON | 59 |
| Blackerby, L.H.(1969) | B | DF | 60 |
| Boldt, C.E.(1969) | J, D, K | PJ | 60 |
| Bolghari, H.A.(1976) | K | PR, PJ | 60 |
| Bolghari, H.A. and Bertrand, V.(1984) | K | NON | 61 |
| Braathe, P.(1957) | J, D | NS, EBE, PS, EF, NS | 61 |
| Bramble, W.C.; Cope, H.N. and Chisman, H.H.(1949) | I, J, K | PR | 62 |
| Brix, H.(1976) | I, J, B | DF | 62 |
| Brown, K.M. and Clarke, F.R.(1987) | D, K, H | PJ, SB | 63 |
| Brunig, E.F. von and Schneider, T.W.(1978) | M | NS, PS | 64 |
| Bublitz, W.J.(1971) | L, J | DF | 64 |
| Buckman, R.E.(1964) | J, I | PJ | 64 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Buijtenen, J.P. van(1969) | L, G, C | NON | 65 |
| Bulger, D.(1987) | B | PJ | 65 |
| Bulger, W.D.(1987) | G | NON | 66 |
| Burger, D.(1972) | H, M | NON | 66 |
| Burschel, P.(1974) | J | NON | 67 |
| Calvert, R.F. and Armson, K.A.(1975) | B, N | PJ | 68 |
| Carmean, W.H. and Lenthall, D.J.(1988) | H, D, K | PJ | 68 |
| Carmichael, A.J.(1968) | L, G | SB | 68 |
| Carmichael, A.J.(n.d.) | L | SB | 69 |
| Carmichael, A.J. and Ladell, J.L.(1967) | L | SB | 69 |
| Carmichael, A.J. and Ladell, J.L.(1966) | B | SB | 69 |
| Carroll, B.(1985) | J, I | PJ | 70 |
| Cayford, J.H.(1966) | J | PJ | 70 |
| Cayford, J.H.(1964) | J | PJ | 71 |
| Cayford, J.H.(1961) | J, K, D | PJ | 71 |
| Cayford, J.H. and Bickerstaff, A.(1968) | D | NON | 71 |
| Chang, C.I. and Kennedy, R.W.(1967) | D | SW | 72 |
| Chrosciewicz, Z.(1971) | D | PJ | 72 |
| Chrosciewicz, Z.(1963) | H, D | PJ | 73 |
| Claughton-Wallin, H. and McVicker, F.(n.d.) | K | PR, PW, SW, DF | 73 |
| Clemmer, E.(n.d.) | B | SB | 73 |
| Cochran, P.H.(1979) | B, D | LPP | 74 |
| Cody, J.B.(1972) | L | PR | 74 |
| Cook, D.B.(1963) | J, I, D | NON | 74 |
| Cregg, B.M.; Dougherty, P.M. and Hennessey, T.C.(1988) | L, D, J | LBLP | 75 |
| Crossley, D.I.(1956) | N, J | LPP, SW | 75 |
| Crouch, G.L.(1986) | J | LPP | 75 |
| Curlin, J.W.(1968) | B | NON | 76 |
| Dahms, W.G.(1973) | K, I, J | LPP | 77 |
| Dahms, W.G.(1971) | K, D | LPP | 77 |
| Davis, K.(1935) | I | NON | 77 |
| Day, M.W. and Rudolph, V.J.(1974) | J, K | SW | 78 |
| Day, M.W. and Rudolph, V.J.(1970) | J, G | SW | 78 |
| Dillon, M.J. and Ladell, J.L.(1966) | L | SB | 79 |
| Dosen, R.C.; Stoeckeler, J.H. and Klip, F.G.(1957) | J | PJ | 79 |
| Drinkwater, M.H.(1957) | D, K | SW | 80 |
| Dunfield, J.D.(1975) | J | NON | 80 |
| Dunfield, J.D.(1974) | J | NON | 80 |
| Edwards, A.(1987) | I, K | NON | 81 |
| Erdmann, G.(1988) | L, I | PR | 81 |
| Eversole, K.R.(1955) | I | DF | 81 |
| Evert, F.(1983) | K, E | SB | 82 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Evert, F. and Lowry, G.L.(1970) | B, D, H, K | SB | 82 |
| Farrar, J.L.(1961) | L, K, J, F | NON | 83 |
| Fayle, D.C.F.(1975) | D | PR | 83 |
| Fielding, J.M.(1967) | L, J, I | NON | 84 |
| Fleming, M.A.(1986) | J | PJ | 84 |
| Foster, E.(1935) | K | NON | 84 |
| Foster, N.W. and Gessel, S.P.(1972) | B | PJ | 85 |
| Foster, N.W. and Morrison, I.K.(1983) | B | PR, DF, PJ, SR, SB, SW, BF | 85 |
| Fowler, D.P.(1986) | C | NON | 86 |
| Fox, G.D. and Kruse, G.W.(1939) | K | SB | 86 |
| Gagnon, J.D.(1965) | B | PR | 87 |
| Gagnon, J.D.(1964) | H, B | SB | 87 |
| Gagnon, J.D.; Conway, J.M. and Swan, H.S.D.(1976) | B | NON | 87 |
| Gary, H.L. and Watkins, R.K.(1985) | J, M | LPP | 88 |
| Gessel, S.P.; Turnbull, K.J. and Tremblay, F.T.(1960) | B, D | NON | 88 |
| Gevorkiantz, S.R.(1949) | K | NON | 88 |
| Godman, R.M. and Cooley, J.H.(1970) | D, K, I | PJ | 88 |
| Godman, R.M. and Olmstead, R.L.(1962) | J, D | PJ | 89 |
| Goodell, B.C.(1952) | J, M | LPP | 89 |
| Gordon, A.M. and Morrow, L.D.(1979) | G, K, D | SB | 89 |
| Gosz, J.R.(1984) | A, D | NON | 90 |
| Govindaraju, D.R.(1984) | G | PJ | 90 |
| Gray, J.L.; Eno, C.F.; Pritchett, W.L.; Smith, W.H. and Gooding, J.W.(1974) | D, B | NON | 90 |
| Gray, R.L. and Kyanka, G.H.(1974) | B | PR | 91 |
| Groot, A.(1982) | B, J | PJ | 91 |
| Groot, A.; Brown, K.M.; Morrison, I.K. and Barker, J.E.(1984) | B, J | PJ | 92 |
| Gross, H.L.; Ek, A.R. and Patton, R.F.(1980) | G, K | PJ | 92 |
| Gross, H.L.; Patton, R.F. and Ek, A.R.(1978) | K, M | PJ | 93 |
| Guilkey, P.C. and Westing, A.H.(1956) | I | PJ | 93 |
| Hagglund, B.(1981) | H, E, K | NON | 94 |
| Hagglund, B. and Lundmark, J.E.(1977) | E, G, H | PS, NS | 94 |
| Hagner, S.O.(1967) | B | NON | 95 |
| Hale, J.D. and Fensom, K.G.(1931) | D, G | SW | 95 |
| Haley, D.(1966) | B, K | NON | 96 |
| Hall, A.D.(1964) | L, D | SB | 96 |
| Hall, A.D.(1963) | K, L | SP, NS, SW | 96 |
| Hall, D.O.(1974) | J, I, D | PP | 97 |
| Hall, J.P.(1986) | D | LA | 97 |
| Hambly, E.S.L.(1980) | D | SB, SW | 98 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Hambly, S.(n.d.) | I, K, G D | NON | 98 |
| Hamilton, G.J.(1976) | J, K, D | NS | 99 |
| Hamilton, G.J.(n.d.) | J, G | NON | 99 |
| Hannula, O.(1971) | K | NON | 100 |
| Hansen, T.S. and Brown, R.M.(1929) | J, D | PJ | 100 |
| Harding, R.B.; Grigal, D.F. and White, E.H.(1985) | A, D, H | SW | 101 |
| Harrington, C.A. and Reukema, D.L.(1983) | D, J, I | DF | 101 |
| Hatcher, R.J.(1964) | D, K, M | SB | 102 |
| Hedin, I.B.(1982) | J | DF, LPP, WHE, CE | 102 |
| Heger, L.(1971) | H, D | SW | 102 |
| Heger, L. and Lowry, G.L.(1971) | K, H | SB | 103 |
| Heger, L. and Lowry, G.L.(1970) | H, D, K, G | SB | 103 |
| Hegyi, F.(1973) | G | PJ | 103 |
| Hegyi, F.(1972) | A, K | PJ | 104 |
| Hegyi, F.(1970) | K | PJ | 104 |
| Hills, G.A.(1960) | H, K | NON | 104 |
| Holmsgaard, E.(1958) | J | NS | 105 |
| Horton, K.W. and Lees, J.C.(1961) | H, C, D | SB, SW | 105 |
| Host, J. and Schlieter, J.(1978) | K, G, M | LPP | 105 |
| Hunt, K.(1977) | K, B, J, A | PJ | 106 |
| Innes, M.R.(1967) | K, M | SW | 107 |
| Jackson, M. and Megraw, R.A.(1986) | D, L | DF | 108 |
| Jeglum, J.K.(1983) | H, D | SB | 108 |
| Jeglum, J.K.(1974) | H, D | SB | 109 |
| Jeglum, J.K.; Haavisto, V.S. and Groot, A.(1982) | H, M | NON | 109 |
| Joergensen, C.(1951) | J | DF | 109 |
| Johnstone, W.D.(1982) | J, K | LPP | 110 |
| Johnstone, W.D.(1982) | I | LPP | 110 |
| Johnstone, W.D.(1981) | J, I, D, K | LPP | 110 |
| Johnstone, W.D.(1981) | J, D, K | LPP | 111 |
| Johnston, W.F.(1977) | D, M | SB | 111 |
| Kabzems, A. and Kirby, C.L.(1956) | J, D | PJ | 112 |
| Kamp, B.J. van der and Spence, M.(1987) | I, M | LPP | 112 |
| Kelertas, R.D.(1977) | B, D | PJ | 113 |
| Ker, M.F.(1976) | K | BW, TA, SB, BF | 113 |
| Khanna, P.H. and Ulrich, B.(1984) | B | NON | 113 |
| Klem, G.S.(1968) | B, L | STW | 114 |
| Knowles, R.(1964) | B, J | SB | 115 |
| Kozlowski, T.T. and Peterson, T.A.(1962) | D | PR | 115 |
| Krabbe, P.(1984) | I, E, J | SB, SW | 116 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Krahmer, R.L.(1986) | C, L | NON | 116 |
| Krause, H.H.(1970) | D | SP, SR, BF | 117 |
| Krause, H.H.; Weetman, G.F. and Koller, E.(1977) | B | BF, PJ, SB | 117 |
| Ladell, J.L.(1971) | D, L | SB | 118 |
| Ladell, J.L.; Carmichael, A.J. and Thomas, G.H.S.(1968) | C | SB | 118 |
| Larson, P.R.(1962) | H, C, J, F, L | NON | 118 |
| Lavigne, M.B.; Donnelly, J.G. and Nostrand, R.S. van(1987) | I, J | SB | 119 |
| Lawrence, J.J. and Melvin, J.C.E.(1967) | J, D | PJ | 119 |
| Lee, R.G.(1986) | L | NON | 120 |
| Leech, R.H.(1969) | B, D, K | PJ | 120 |
| Long, J.N. and McCarter, J.B.(1985) | D | LPP | 121 |
| Low, A.J.(1974) | J, I | NON | 121 |
| Lowell, K.E. and Dwyer, J.P.(1988) | J, F, K | NON | 121 |
| Lowry, G.L.(1975) | H | SB | 122 |
| Lowry, G.L.(1972) | G, H, B | SB | 122 |
| Lowry, G.L. and Avard, P.M.(1969) | G, B | SB, PJ | 123 |
| Lowry, G.L. and Avard, P.M.(1967) | G, H, B, D, K | SB | 123 |
| Lowry, G.L. and Avard. P.M.(1965) | B | SB | 123 |
| Lozano, F.C. and Parton, W.J.(1988) | B, C | SB | 124 |
| Lozano, F.C. and Parton, W.J.(1986) | B | SB | 124 |
| Lundgren, A.L.(1981) | I, J, K | PR | 124 |
| MacArthur, J.D.(1959) | D | SW, PJ, PR, PS | 125 |
| MacDougall, F.A.(1959) | B | PR | 125 |
| MacLean, D.A. and Wein, R.W.(1976) | K, A | PJ | 125 |
| MacLean, D.W. and Bedell, G.H.D.(1955) | K, H, D | NON | 126 |
| Maki, T.E.(1958) | B, M | NON | 126 |
| Malcolm, D.C.(1976) | G, H | SS | 126 |
| Maloney, T.M.(1986) | L | DF | 127 |
| Manchester, D.F. and Naysmith, D.(n.d.) | C, L, D | PJ | 127 |
| Manning, G.H.(1987) | E, K, I, J, B, D | NON | 127 |
| Marts, R.O.(1951) | L, D | LPP | 128 |
| Mattice, C.R. and Curtis, F.W.(1978) | J | NON | 128 |
| McIntosh, R.(1984) | J, K | PS, SS, NS | 129 |
| McKimmy, M.D.(1986) | B, J, I, L | NON | 129 |
| McMinn, R.G.(1986) | K, M | SW | 130 |
| McMullan, D.(1987) | D | NON | 130 |
| Meng, C.H.(1981) | J, B, K | SB | 130 |
| Meylan, B.A.(1968) | L | PJE, PM | 131 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Miller, H.G.; Cooper, J.M.; Miller, J.D and Pauline, O.J.L.(1979) | B, D | PA | 131 |
| Miller, H.G.; Miller, J.D. and Cooper, J.M.(1981) | D, K | PA | 132 |
| Mirov, N.T.(1956) | C, M | LPP, PJ | 132 |
| Mitchell, K.J.(1969) | D, E | SW | 132 |
| Mitchell, K.J. and Kellogg, R.M.(1972) | B | DF | 133 |
| Moller, C.M.(1947) | A, H, J | NON | 133 |
| Moore, B.(1926) | D | NON | 134 |
| Morrison, I.K.(1974) | B | PJ | 134 |
| Morrison, I.K.(1973) | B | PJ | 134 |
| Morrison, I.K.(1972) | B, A | PJ | 135 |
| Morrison, I.K. and Armson, K.A.(1968) | D, B | NON | 135 |
| Morrison, I.K. and Foster, N.W.(1979) | D, K, B | SW, SB, BF | 135 |
| Morrison, I.K.; Hegyi, F.; Foster, N.W.; Winston, D.A. and Tucker, T.L.(1976) | B | PJ | 136 |
| Morrison, I.K.; Swan, H.S.D.; Foster, N.W. and Winston, D.A.(1977) | K, B, D | PJ | 136 |
| Morrison, I.K.; Winston, D.A. and Foster, N.W.(1977) | B, D | PJ | 136 |
| Morrison, I.K.; Winston, D.A. and Foster, N.W.(1977) | B, K | PJ | 137 |
| Morrison, I.K.; Winston, D.A. and Foster, N.W.(1976) | B, K | PJ | 137 |
| Mullin, R.E.(1979) | D | PJ | 137 |
| Munro, D.(n.d.) | A, D | SB | 137 |
| Mustanoja, K.J. and Leaf, A.L.(1965) | B, D, L, M | NON | 138 |
| Myren, D.T.(1981) | J, M | PR, PJ | 138 |
| Nicks, B.D.(1977) | B | PJ | 139 |
| Niznowski, G.P.(1988) | G, K | PJ, LPP | 139 |
| Nostrand, R.S. van(1979) | B | SB | 140 |
| Nostrand, R.S. van(1975) | I, B | SB, SS, BF | 140 |
| Oliver, C.D.(1986) | L | DF | 141 |
| Oliver, W.W.(1979) | I, D | PP | 141 |
| Olson, J.T.; Lundgren, A.L. and Rose, D.(1978) | J, M | NON | 142 |
| Page, G.(1976) | H, G | BF, SB | 143 |
| Patton, R.F. and Krebill, R.G.(1960) | D | PJ, PR | 143 |
| Payandeh, B.(1986) | H | SB | 144 |
| Payandeh, B.(1986) | E | NON | 144 |
| Payandeh, B.(1978) | H, K | SB | 145 |
| Payandeh, B.(1975) | I, K, E | PR | 145 |
| Payandeh, B.(1975) | E, I | SB | 145 |
| Payandeh, B.(1974) | E | SB, PJ, PR, PW, HW, BW | 146 |
| Payandeh, B.(n.d.) | E | NON | 146 |
| Perala, D.A.(1971) | D, K | SB | 147 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Phu, T.D.(1975) | B, H | PR | 147 |
| Phu, T.D. and Gagnon, J.D.(1975) | B, D | SW | 148 |
| Pienaar, L.V.; Shiver, B.D. and Grider, G.E.(1985) | D, J, E | PSL | 148 |
| Popovich, S. and Houle, N.(1970) | D | SB, PR, NS, PJ, LA, JLA | 149 |
| Porterfield, R.L. and Schweitzer, D.L.(1975) | J | LPP | 149 |
| Radwin, M.A. and Brix, H.(1986) | B | DF | 150 |
| Ralston, R.A.(1953) | J, I | PJ | 150 |
| Rennie, P.J.(1972) | B, C | WHE, DF | 150 |
| Rennie, P.J.(1963) | H, K, A | NON | 151 |
| Righter, F.I.(1922) | J | NON | 151 |
| Riley, L.F.(1973) | D, J, I | NON | 152 |
| Riley, L.F.(1973) | J | PJ | 152 |
| Roberge, M.R. and Knowles, R.(1965) | B | SB | 153 |
| Robertson, A.(1986) | K | HW | 153 |
| Roche, L.(1970) | C, B | NON | 154 |
| Roe, E.I. and Stoeckeler, J.H.(1950) | J | PJ | 154 |
| Roeser, J.(1932) | J, D | PJ | 154 |
| Rowe, J.S.(1962) | H, K | NON | 155 |
| Rudolf, P.O.(1951) | I, M | PJ | 155 |
| Sadiq, R.A. and Smith, V.G.(1983) | K | NON | 156 |
| Salonius, P.O.; Fisher, R.A. and Mahendrappa, M.K.(1982) | B, E | SB | 156 |
| Sandvik, M.(1986) | H | PS, LPP, NS | 157 |
| Schantz-Hansen, T.(1934) | J, L | PJ | 157 |
| Schenk, J.A.; Dosen, R.C. and Benjamin, D.M.(1957) | J, M | PJ | 157 |
| Schlaegel, B.E.(1975) | D, K, L | NON | 158 |
| Schmidt, M.G. and Carmean, W.H.(1987) | H, G | PJ | 158 |
| Schnekenburger, F.(1983) | B, J, D | PJ | 159 |
| Scott, S.L.; Barker, J.E.; Morrison, I.K. and Foster, N.W.(1982) | B, J | PJ | 159 |
| Selin, L.O.(1977) | J | NON | 160 |
| Senft, J.F.; Quanci, M.J. and Bendtsen, B.A.(1986) | B | DF | 160 |
| Shea, S.R.(1981) | K, E, I, J, B, C | PJ | 161 |
| Shea, S.R. and Armson, K.A.(1972) | D | NON | 161 |
| Sjolte-Jorgensen, J.(1967) | I | NS | 161 |
| Skeates, D.A.(1979) | D | PJ | 162 |
| Smissaert, C.(1988) | J, K | NON | 162 |
| Smith, C.R.; Johnson, J.D. and Riley, L.F.(1986) | D, J | PJ | 163 |
| Smith, D.M.(1968) | L, J | LBLP | 163 |
| Smith, J.H.G.(1986) | I | NON | 163 |
| Smith, J.H.G.(1959) | I, J | NON | 164 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Smith, J.H.G.(1958) | I, D, J, F, | LDF | 164 |
| Smith, N.J. and Brand, D.G.(1987) | E, K | PR | 164 |
| Smith, V.G.(1983) | K | NON | 165 |
| Smith, V.G.(1983) | K, H | SB | 165 |
| Smith, W.R. and Briggs, D.G.(1986) | L | NON | 165 |
| Smithers, L.A.(1957) | J, K | LPP | 166 |
| Smithers, L.A.(1954) | J, F, D | PR, PW | 166 |
| Solomon, D.S.; Hosmer, R.A. and Hayslett, H.T.(1987) | D, E | STW, BF, SB, SR, SW, HE, BG, BY, BW, CE, SM, RM, AW, TA, STM, PCH, AB, LA, PW | 167 |
| Spurr, S.H.(1955) | H, D, G | DF, PR | 167 |
| Spurr, S.H. and Hsiung, W.(1954) | L, D | PJ | 168 |
| Steinbrenner, E.C.(1970) | B | DF | 168 |
| Steneker, G.A.(1969) | J | PJ, SB | 169 |
| Stiell, W.M.(1986) | H, K, D, C | SW | 169 |
| Stiell, W.M.(1986) | I | LA | 170 |
| Stiell, W.M.(1970) | J | SW | 170 |
| Stiell, W.M.(1968) | I, K | NON | 170 |
| Stiell, W.M.(1964) | I | PR | 171 |
| Stiell, W.M.(1955) | D | PS, PR, PW, SW | 171 |
| Stiell, W.M. and Berry, A.B.(1977) | I, G | PR | 171 |
| Stone, E.L.(1958) | B | NON | 172 |
| Swan, H.S.D.(1970) | B | NON | 172 |
| Swan, H.S.D.(1970) | B | SB, PJ | 173 |
| Swan, H.S.D.(1968) | B | NON | 173 |
| Swan, H.S.D.(1967) | B | NON | 174 |
| Swan, H.S.D.(1966) | B | PJ | 174 |
| Swan, H.S.D.(1965) | B | NON | 175 |
| Swan, H.S.D.(1965) | B | SW, SB, NS, SR, PJ, DF, ELA, DLA | 175 |
| Swan, H.S.D.(1963) | B | NON | 176 |
| Swan, H.S.D.(1962) | B | SW, NS, PJ, PR, PS | 176 |
| Swan, H.S.D.(n.d.) | B | NON | 176 |
| Tamm, C.O.(1958) | B | NON | 177 |
| Tappeiner, J.C.; Bell, J.F. and Brodie, J.D.(1982) | D, J, K | DF | 177 |
| Thomson, A.J. and Barclay, H.J.(1984) | J, B, D, G | DF | 177 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Timonen, M. and Varmola, M.(1986) | K, D | PS | 178 |
| Towill, W.D. and Siczkar, L.A.(1988) | I, K | SB, SW, PR, PW | 178 |
| Towill, W.D. and Siczkar, L.A.(1988) | H | NON | 178 |
| Udell, R.W. and Dempster, W.R.(1987) | K, E | LPP | 179 |
| Urie, D.H.(1971) | J, M | PJ | 179 |
| Vassov, R. and Baker, W.D.(1988) | I, D | PJ | 180 |
| Vezina, P.E.(1965) | D | BF, SB, PJ | 180 |
| Vezina, P.E.(1964) | J, E | BF | 181 |
| Vezina, P.E.(1964) | A, D, I | PJ, BF | 181 |
| Vezina, P.E.(1963) | J | PJ | 181 |
| Vezina, P.E.(1963) | J | NON | 182 |
| Vezina, P.E. and Pech, G.(1964) | J | BF, PR, PJ | 182 |
| Vincent, A.B.(1962) | A, D, K | SB | 182 |
| Voorhies, G.(1982) | J, L | PP | 183 |
| Walker, L.C.(1968) | B | NON | 184 |
| Wambach, R.F.(1967) | I, G | PR | 184 |
| Watt, R.F. and Heinselman, M.L.(1965) | H | SB | 185 |
| Weber, M.G. and Cleve, K. van(1984) | B | SB | 185 |
| Weetman, G.F.(1975) | B, J, K | SB | 186 |
| Weetman, G.F.(1967) | B | SB | 186 |
| Weetman, G.F.(1966) | B, D | SW | 187 |
| Weetman, G.F. and Algar, D.(1974) | B | PJ | 188 |
| Weetman, G.F. and Fournier, R.M.(1984) | B, D | P | 188 |
| Weetman, G.F. and Fournier, R.M.(1984) | B, D | PJ | 189 |
| Weetman, G.F. and Harland, R.(1964) | G, K, D | SB | 189 |
| Weetman, G.F.; Roberge, M.R. and Meng, C.H.(1980) | B, J, D, K | SB | 190 |
| Weetman, G.F. and Webber, B.(1972) | B | SR, SB, BF | 191 |
| Weihe, J.(1977) | J, D | NS | 191 |
| Weihe, V.J.(1978) | J, H | NS | 192 |
| White, D.P.(1958) | B, M | NON | 192 |
| Wilde, S.A.; Benson, H.P. and Mikola, P.(1951) | K, L | PJ | 192 |
| Wilde, S.A.; Giordano, A.; Shaw, B.H.; Fedkenheuer, A.W. and Seip, W.T.(1968) | I | PJ, PR, PW | 192 |
| Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1965) | H, K | PJ, PR, PW, SW, BF | 193 |
| Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1964) | D, G, H | PJ | 193 |
| Willcocks, A.J.(1978) | D, K | SW | 193 |
| Wilson, F.G.(1979) | J, K | PR | 193 |
| Wilson, F.G.(1955) | J, K | PR | 194 |
| Wilson, G.M.(1952) | I, J, D | PJ | 194 |

| AUTHOR | SUBJ. | SPECIES | PAGE |
|---|---|---|---|
| Wilson, G.M.(1951) | J | PJ | 194 |
| Winston, D.A.(1977) | B, J, I | PJ | 194 |
| Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) | B, N | PJ | 195 |
| Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) | D, B, J | PJ | 195 |
| Wood, J.E. and Dominy, S.W.J.(1985) | D | SB, SW, PJ | 196 |
| Woodhead, P.V.(1934) | J | LPP | 196 |
| Woods, M.E. and Beckwith, A.F.(1987) | K | SB | 197 |
| Yang, K.C.(1987) | L | NON | 198 |
| Yang, K.C.(1987) | L, C, I, J, B, F | NON | 198 |
| Yang, K.C. and Hazenberg, G.(1987) | L, D, C | LA | 199 |
| Yang, R.C.(1986) | I | LPP | 199 |
| York, E.T.(1958) | B, C | NON | 199 |
| Zahner, R. and Oliver, W.W.(1962) | L, J, F | PR, PJ | 200 |
| Zavitkovski, J. and Dawson, D.H.(1978) | A, I, G | PJ | 200 |
| Zehngraff, P. and Zasada, Z.A.(1949) | D, K, G | PR | 200 |
| Zeide, B.(1978) | H, K | NON | 200 |
| Zobel, B.(1981) | L | NON | 201 |
| Zobel, B.J.(1970) | K | NON | 201 |

# SPECIES/SUBJECT INDEX

**JACK PINE** **PAGE**

BIOMASS

Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) 37
Alemdag, I.S.(1982) 38
Hegyi, F.(1972) 104
Hunt, K.(1977) 106
MacLean, D.A. and Wein, R.W.(1976) 125
Morrison, I.K.(1972) 135
Vézina, P.E.(1964) 181
Zavitkovski, J. and Dawson, D.H.(1978) 200

FERTILIZATION

Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) 37
Armson, K.A.(1975) 44
Armson, K.A.(1972) 45
Bulger, D.(1987) 65
Calvert, R.F. and Armson, K.A.(1975) 68
Foster, N.W. and Gessel, S.P.(1972) 85
Foster, N.W. and Morrison, I.K.(1983) 85
Groot, A.(1982) 91
Groot, A.; Brown, K.M.; Morrison, I.K. and Barker, J.E.(1984) 92
Hunt, K.(1977) 106
Kelertas, R.D.(1977) 113
Krause, H.H.; Weetman, G.F. and Koller, E.(1977) 117
Leech, R.H.(1969) 120
Lowry, G.L. and Avard, P.M.(1969) 123
Morrison, I.K.(1974) 134
Morrison, I.K.(1973) 134
Morrison, I.K.(1972) 135
Morrison, I.K.; Hegyi, F.; Foster, N.W.; Winston, D.A. and Tucker, T.L.(1976) 136
Morrison, I.K.; Swan, H.S.D.; Foster, N.W. and Winston, D.A.(1977) 136
Morrison, I.K.; Winston, D.A. and Foster, N.W.(1977) 136
Morrison, I.K.; Winston, D.A. and Foster, N.W.(1977) 137
Morrison, I.K.; Winston, D.A. and Foster, N.W.(1976) 137
Nicks, B.D.(1977) 139
Schnekenburger, F.(1983) 159
Scott, S.L.; Barker, J.E.; Morrison, I.K. and Foster, N.W.(1982) 159
Shea, S.R.(1981) 161
Swan, H.S.D.(1970) 173
Swan, H.S.D.(1966) 174
Swan, H.S.D.(1965) 175
Swan, H.S.D.(1962) 176
Weetman, G.F. and Algar, D.(1974) 188

**JACK PINE cont.** **PAGE**

Fertilization cont.

Weetman, G.F. and Fournier, R.M.(1984) 188
Weetman, G.F. and Fournier, R.M.(1984) 189
Winston, D.A.(1977) 194
Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) 195
Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) 195

GENETICS

Manchester, D.F. and Naysmith, D.(n.d.) 127
Mirov, N.T.(1956) 132
Shea, S.R.(1981) 161

GROWTH AND DEVELOPMENT

Alban, D.H.(1978) 37
Allison, J.H.(1952) 40
Bella, I.E.(1974) 51
Bella, I.E.(1967) 52
Bella, I.E.(1966) 53
Bella, I.E. and DeFrancheschi, J.P.(1974) 56
Benzie, J.W.(1977) 57
Boldt, C.E.(1969) 60
Brown, K.M. and Clarke, F.R.(1987) 63
Carmean, W.H. and Lenthall, D.J.(1988) 68
Cayford, J.H.(1961) 71
Chrosciewicz, Z.(1971) 72
Chrosciewicz, Z.(1963) 73
Godman, R.M. and Cooley, J.H.(1970) 88
Godman, R.M. and Olmstead, R.L.(1962) 89
Hansen, T.S. and Brown, R.M.(1929) 100
Kabzems, A. and Kirby, C.L.(1956) 112
Kelertas, R.D.(1977) 113
Lawrence, J.J. and Melvin, J.C.E.(1967) 119
Leech, R.H.(1969) 120
MacArthur, J.D.(1959) 125
Manchester, D.F. and Naysmith, D.(n.d.) 127
Morrison, I.K.; Swan, H.S. D.; Foster, N.W. and Winston, D.A.(1977) 136
Morrison, I.K.; Winston, D.A. and Foster, N.W.(1977) 136
Mullin, R.E.(1979) 137
Patton, R.F. and Krebill, R.G.(1960) 143
Popovich, S. and Houle, N.(1970) 149
Roeser, J.(1932) 154
Schnekenburger, F.(1983) 159
Skeates, D.A.(1979) 162
Smith, C.R.; Johnson, J.D. and Riley, L.F.(1986) 163

**JACK PINE cont.** **PAGE**

GROWTH AND DEVELOPMENT cont.

Spurr, S.H. and Hsiung, W.(1954) 168
Vassov, R. and Baker, W.D.(1988) 180
Vézina, P.E.(1965) 180
Vézina, P.E.(1964) 181
Weetman, G.F. and Fournier, R.M.(1984) 188
Weetman, G.F. and Fournier, R.M.(1984) 189
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1964) 193
Wilson, G.M.(1952) 194
Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) 195
Wood, J.E. and Dominy, S.W.J.(1985) 196

MODELLING

Payandeh, B.(1974) 146
Shea, S.R.(1981) 161

PRUNING

Zahner, R. and Oliver, W.W.(1962) 200

SAMPLING AND DATA ANALYSIS

Armson, K.A.(1972) 45
Govindaraju, D.R.(1984) 90
Gross, H.L.; Ek, A.R. and Patton, R.F.(1980) 92
Hegyi, F.(1973) 103
Lowry, G.L. and Avard, P.M.(1969) 123
Niznowski, G.P.(1988) 139
Schmidt, M.G. and Carmean, W.H.(1987) 158
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1964) 193
Zavitkovski, J. and Dawson, D.H.(1978) 200

SITE INDEX

Brown, K.M. and Clarke, F.R.(1987) 63
Carmean, W.H. and Lenthall, D.J.(1988) 68
Chrosciewicz, Z.(1963) 73
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1965) 193
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1964) 193

**JACK PINE cont.** **PAGE**

SPACING

Bella, I.E.(1986) 50
Bella, I.E. and DeFrancheschi, J.P.(1980) 54
Bella, I.E. and DeFrancheschi, J.P.(1974) 55
Buckman, R.E.(1964) 64
Carroll, B.(1985) 70
Godman, R.M. and Cooley, J.H.(1970) 88
Guilkey, P.C. and Westing, A.H.(1956) 93
Ralston, R.A.(1953) 150
Rudolf, P.O.(1951) 155
Shea, S.R.(1981) 161
Vassov, R. and Baker, W.D.(1988) 180
Vézina, P.E.(1964) 181
Wilde, S.A.; Giordano, A.; Shaw, B.H.; Fedkenheuer, A.W. and Seip, W.T.(1968) 192
Wilson, G.M.(1952) 194
Winston, D.A.(1977) 194
Zavitkovski, J. and Dawson, D.H.(1978) 200

THINNING/RELEASE CUTTING

Alm, A.A. and Schantz-Hansen, R.(1970) 41
Alm, A.A.; Pflager, S.M. and Schantz-Hansen, R.(1979) 41
Bella, I.E.(1985) 50
Bella, I.E.(1974) 51
Bella, I.E.(1967) 52
Bella, I.E.(1966) 53
Bella, I.E. and DeFrancheschi, J.P.(1974) 54
Bella, I.E. and DeFrancheschi, J.P.(1974) 55
Boldt, C.E.(1969) 60
Buckman, R.E.(1964) 64
Carroll, B.(1985) 70
Cayford, J.H.(1966) 70
Cayford, J.H.(1964) 71
Cayford, J.H.(1961) 71
Dosen, R.C.; Stoeckeler, J.H. and Klip, F.G.(1957) 79
Fleming, M.A.(1986) 84
Godman, R.M. and Olmstead, R.L.(1962) 89
Groot, A.(1982) 91
Groot, A.; Brown, K.M.; Morrison, I.K. and Barker, J.E.(1984) 92
Hansen, T.S. and Brown, R.M.(1929) 100
Hunt, K.(1977) 106
Kabzems, A. and Kirby, C.L.(1956) 112
Lawrence, J.J. and Melvin, J.C.E.(1967) 119
Myren, D.T.(1981) 138
Ralston, R.A.(1953) 150
Riley, L.F.(1973) 152
Roe, E.I. and Stoeckeler, J.H.(1950) 154

**JACK PINE cont.** **PAGE**

THINNING/RELEASE CUTTING cont.

Roeser, J.(1932) 154
Schantz-Hansen, T.(1934) 157
Schenk, J.A.; Dosen, R.C. and Benjamin, D.M.(1957) 157
Schnekenburger, F.(1983) 159
Scott, S.L.; Barker, J.E.; Morrison, I.K. and Foster, N.W.(1982) 159
Shea, S.R.(1981) 161
Smith, C.R.; Johnson, J.D. and Riley, L.F.(1986) 163
Steneker, G.A.(1969) 169
Urie, D.H.(1971) 179
Vézina, P.E.(1963) 181
Vézina, P.E. and Péch, G.(1964) 182
Wilson, G.M.(1952) 194
Wilson, G.M.(1951) 194
Winston, D.A.(1977) 194
Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) 195
Zahner, R. and Oliver, W.W.(1962) 200

VOLUME/YIELD TABLES/EQUATIONS

Allison, J.H.(1952) 40
Bella, I.E.(1986) 50
Bella, I.E.(1971) 52
Bella, I.E.(1968) 52
Bella, I.E.(1967) 52
Benzie, J.W.(1977) 57
Boldt, C.E.(1969) 60
Bolghari, H.A.(1976) 60
Brown, K.M. and Clarke, F.R.(1987) 63
Carmean, W.H. and Lenthall, D.J.(1988) 68
Cayford, J.H.(1961) 71
Godman, R.M. and Cooley, J.H.(1970) 88
Gross, H.L.; Ek, A.R. and Patton, R.F.(1980) 92
Gross, H.L.; Patton, R.F. and Ek, A.R.(1978) 93
Hegyi, F.(1972) 104
Hegyi, F.(1970) 104
Hunt, K.(1977) 106
Leech, R.H.(1969) 120
MacLean, D.A. and Wein, R.W.(1976) 125
Morrison, I.K.; Swan, H.S. D.; Foster, N.W. and Winston, D.A.(1977) 136
Morrison, I.K.; Winston, D.A. and Foster, N.W.(1977) 137
Morrison, I.K.; Winston, D.A. and Foster, N.W.(1976) 137
Niznowski, G.P.(1988) 139
Shea, S.R.(1981) 161
Wilde, S.A.; Benson, H.P. and Mikola, P.(1951) 192
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1965) 193

**JACK PINE cont.** **PAGE**

WOOD QUALITY

Bella, I.E. and Defrancheschi, J.P.(1974) 55
Manchester, D.F. and Naysmith, D.(n.d.) 126
Schantz-Hansen, T.(1934) 157
Spurr, S.H. and Hsiung, W.(1954) 168
Wilde, S.A.; Benson, H.P. and Mikola, P.(1951) 192
Zahner, R. and Oliver, W.W.(1962) 200

OTHER

Gross, H.L.; Patton, R.F. and Ek, A.R.(1978) 93
Mirov, N.T.(1956) 132
Myren, D.T.(1981) 138
Rudolf, P.O.(1951) 155
Schenk, J.A.; Dosen, R.C. and Benjamin, D.M.(1957) 157
Urie, D.H.(1971) 179

HERBICIDES

Calvert, R.F. and Armson, K.A.(1975) 68
Winston, D.A.; Morrison, I.K. and Foster, N.W.(1977) 195

**LODGEPOLE PINE** **PAGE**

FERTILIZATION

Anon.(1982) 43
Anon.(1982) 43
Cochran, P.H.(1979) 74

GENETICS

Alexander, R.R.; Lotan, J.E.; Larson, J.M. and Volland, A.L.(n.d.) 40
Mirov, N.T.(1956) 132

GROWTH AND DEVELOPMENT

Ackerman, R.F.(1962) 36
Alexander, R.R.(1960) 39
Alexander, R.R.(1956) 40
Ballard, L.A. and Long, J.N.(1988) 48
Benson, R.E. and Strong, R.A.(1977) 57
Cochran, P.H.(1979) 74
Dahms, W.G.(1971) 77
Johnstone, W.D.(1981) 110
Johnstone, W.D.(1981) 111
Long, J.N. and McCarter, J.B.(1985) 121
Marts, R.O.(1951) 128

MODELLING

Udell, R.W. and Dempster, W.R.(1987) 179

SAMPLING/DATA ANALYSIS

Niznowski, G.P.(1988) 139

SITE INDEX

Sandvik, M.(1986) 157

SPACING

Anon.(1982) 43
Anon.(1982) 43
Dahms, W.G.(1973) 77
Johnstone, W.D.(1982) 110

**LODGEPOLE PINE cont.** **PAGE**

SPACING cont.

Johnstone, W.D.(1981) 110
Kamp, B.J. van der and Spence, M.(1987) 112
Yang, R.C.(1986) 199

THINNING/RELEASE CUTTING

Alexander, R.R.(1965) 39
Alexander, R.R.(1960) 39
Alexander, R.R.(1956) 40
Alexander, R.R. and Edminster, C.B.(1981) 40
Anon.(1982) 43
Bella, I.E.(1985) 50
Bella, I.E.(1974) 51
Bella, I.E.(1972) 51
Bella, I.E. and DeFrancheschi, J.P.(1982) 53
Bella, I.E. and DeFrancheschi, J.P.(1977) 54
Crossley, D.I.(1956) 75
Crouch, G.L.(1986) 75
Dahms, W.G.(1973) 77
Gary, H.L. and Watkins, R.K.(1985) 88
Goodell, B.C.(1952) 89
Hedin, I.B.(1982) 102
Johnstone, W.D.(1982) 110
Johnstone, W.D.(1981) 110
Johnstone, W.D.(1981) 111
Porterfield, R.L. and Schweitzer, D.L.(1975) 149
Smithers, L.A.(1957) 166

VOLUME/YIELD TABLES/EQUATIONS

Ackerman, R.F.(1962) 36
Alexander, R.R. and Edminster, C.B.(1981) 40
Bella, I.E.(1974) 51
Dahms, W.G.(1973) 77
Dahms, W.G.(1971) 77
Host, J. and Schlieter, J.(1978) 105
Johnstone, W.D.(1982) 110
Johnstone, W.D.(1981) 110
Johnstone, W.D.(1981) 111
Niznowski, G.P.(1988) 139
Smithers, L.A.(1957) 166
Udell, R.W. and Dempster, W.R.(1987) 179

**LODGEPOLE PINE cont.** **PAGE**

WOOD QUALITY

Marts, R.O.(1951) 128

OTHER

Gary, H.L. and Watkins, R.K.(1985) 88
Goodell, B.C.(1952) 89
Host, J. and Schlieter, J.(1978) 105
Kamp, B.J. van der and Spence, M.(1987) 112
Mirov, N.T.(1956) 132

HERBICIDES

Crossley, D.I.(1956) 75

**RED PINE** **PAGE**

BIOMASS

Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) 37
Alemdag, I.S. and Stiell, W.M.(1982) 39
Berry, A.B.(1984) 58

FERTILIZATION

Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) 37
Foster, N.W. and Morrison, I.K.(1983) 85
Gagnon, J.D.(1965) 87
Gray, R.L. and Kyanka, G.H.(1974) 91
MacDougall, F.A.(1959) 125
Phu, T.D.(1975) 147
Swan, H.S.D.(1962) 176

GROWTH AND DEVELOPMENT

Alban, D.H.(1978) 37
Bazeley, D.G.(1988) 49
Berry, A.B.(1969) 58
Fayle, D.C.F.(1975) 83
Kozlowski, T.T. and Peterson, T.A.(1962) 115
MacArthur, J.D.(1959) 125
Patton, R.F. and Krebill, R.G.(1960) 143
Popovich, S. and Houle, N.(1970) 149
Smithers, L.A.(1954) 166
Spurr, S.H.(1955) 167
Stiell, W.M.(1955) 171
Zehngraff, P. and Zasada, Z.A.(1949) 200

MODELLING

Payandeh, B.(1975) 145
Payandeh, B.(1974) 146
Smith, N.J. and Brand, D.G.(1987) 164

PRUNING

Smithers, L.A.(1954) 166
Zahner, R. and Oliver, W.W.(1962) 200

**RED PINE cont.** **PAGE**

SAMPLING AND DATA ANALYSIS

Spurr, S.H.(1955) 167
Stiell, W.M. and Berry, A.B.(1977) 171
Wambach, R.F.(1967) 184
Zehngraff, P. and Zasada, Z.A.(1949) 200

SITE INDEX

Phu, T.D.(1975) 147
Spurr, S.H.(1955) 167
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1965) 193

SPACING

Alemdag, I.S. and Stiell, W.M.(1982) 39
Bella, I.E.(1986) 50
Bella, I.E. and DeFrancheschi, J.P.(1980) 54
Bella, I.E. and DeFrancheschi, J.P.(1974) 55
Berry, A.B.(1969) 58
Berry, A.B.(1969) 59
Bramble, W.C.; Cope, H.N. and Chisman, H.H.(1949) 62
Erdmann, G.(1988) 81
Lundgren, A.L.(1981) 124
Payandeh, B.(1975) 145
Stiell, W.M.(1964) 171
Stiell, W.M. and Berry, A.B.(1977) 171
Towill, W.D. and Siczkar, L.A.(1988) 178
Wambach, R.F.(1967) 184
Wilde, S.A.; Giordano, A.; Shaw, B.H.; Fedkenheuer, A.W. and Seip, W.T.(1968) 192

THINNING/RELEASE CUTTING

Althen, F.W. von; Stiell, W.M. and Forster, R.B.(1978) 41
Andison, D.; Roebbelen, P. and Beckwith, A.F.(1984) 42
Berry, A.B.(1969) 58
Berry, A.B.(1969) 59
Bramble, W.C.; Cope, H.N. and Chisman, H.H.(1949) 62
Lundgren, A.L.(1981) 124
Myren, D.T.(1981) 138
Smithers, L.A.(1954) 167
Vézina, P.E. and Péch, G.(1964) 182
Wilson, F.G.(1979) 193
Wilson, F.G.(1955) 194
Zahner, R. and Oliver, W.W.(1962) 200

**RED PINE cont.** **PAGE**

VOLUME\YIELD TABLES\EQUATIONS

Alemdag, I.S.(1988) 38
Baker, G.(1967) 48
Bella, I.E.(1986) 50
Berry, A.B.(1984) 58
Bolghari, H.A.(1976) 60
Bramble, W.C.; Cope, H.N. and Chisman, H.H.(1949) 62
Claughton-Wallin, H. and McVicker, F.(n.d.) 73
Lundgren, A.L.(1981) 124
Payandeh, B.(1975) 145
Smith, N.J. and Brand, D.G.(1987) 164
Towill, W.D. and Siczkar, L.A.(1988) 178
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G(1965) 193
Wilson, F.G.(1979) 193
Wilson, F.G.(1955) 194
Zehngraff, P. and Zasada, Z.A.(1949) 200

WOOD QUALITY

Baker, G.(1967) 48
Bazeley, D.G.(1988) 49
Cody, J.B.(1972) 74
Erdmann, G.(1988) 81
Zahner, R. and Oliver, W.W.(1962) 200

OTHER

Myren, D.T.(1981) 138

**BLACK SPRUCE** **PAGE**

BIOMASS

Alemdag, I.S.(1982) 38
Munro, D.(n.d.) 137
Vincent, A.B.(1962) 182

FERTILIZATION

Alban, D.H. and Watt, R.F.(1981) 37
Carmichael, A.J. and Ladell, J.L.(1966) 69
Clemmer, E.(n.d.) 73
Evert, F. and Lowry, G.L.(1970) 82
Foster, N.W. and Morrison, I.K.(1983) 85
Gagnon, J.D.(1964) 87
Knowles, R. (1964) 115
Krause, H.H.; Weetman, G.F. and Koller, E.(1977) 117
Lowry, G.L.(1972) 122
Lowry, G.L. and Avard, P.M.(1967) 123
Lowry, G.L. and Avard, P.M.(1969) 123
Lowry, G.L. and Avard. P.M.(1965) 123
Lozano, F.C. and Parton, W.J.(1988) 124
Lozano, F.C. and Parton, W.J.(1986) 124
Meng, C.H.(1981) 130
Morrison, I.K. and Foster, N.W.(1979) 135
Nostrand, R.S. van(1975) 140
Nostrand, R.S. van(1979) 140
Roberge, M.R. and Knowles, R.(1965) 153
Salonius, P.O.; Fisher, R.A. and Mahendrappa, M.K.(1982) 156
Swan, H.S.D.(1970) 173
Swan, H.S.D.(1965) 175
Weber, M.G. and Cleve, K. van(1984) 185
Weetman, G.F.(1975) 186
Weetman, G.F.(1967) 186
Weetman, G.F. and Webber, B.(1972) 191
Weetman, G.F.; Roberge, M.R. and Meng, C.H.(1980) 190

GENETICS

Horton, K.W. and Lees, J.C.(1961) 105
Ladell, J.L.; Carmichael, A.J. and Thomas, G.H.S.(1968) 118
Lozano, F.C. and Parton, W.J.(1988) 124

**BLACK SPRUCE cont.** **PAGE**

GROWTH AND DEVELOPMENT


Alban, D.H. and Watt, R.F.(1981) 37
Anon.(1968) 43
Benson, J.A.(1973) 57
Brown, K.M. and Clarke, F.R.(1987) 63
Evert, F. and Lowry, G.L.(1970) 82
Gordon, A.M. and Morrow, L.D.(1979) 89
Hall, A.D.(1964) 96
Hambly, E.S.L.(1980) 98
Hatcher, R.J.(1964) 102
Heger, L. and Lowry, G.L.(1970) 103
Horton, K.W. and Lees, J.C.(1961) 105
Jeglum, J.K.(1983) 108
Jeglum, J.K.(1974) 109
Johnston, W.F.(1977) 111
Ladell, J.L.(1971) 118
Lowry, G.L. and Avard, P.M.(1967) 123
Morrison, I.K. and Foster, N.W. (1979) 135
Munro, D.(n.d.) 137
Perala, D.A.(1971) 146
Popovich, S. and Houle, N.(1970) 149
Solomon, D.S.; Hosmer, R.A. and Hayslett, H.T.(1987) 167
Vézina, P.E.(1965) 180
Vincent, A.B.(1962) 182
Weetman, G.F. and Harland, R.(1964) 189
Weetman, G.F.; Roberge, M.R. and Meng, C.H.(1980) 190
Wood, J.E. and Dominy, S.W.J.(1985) 196


MODELLING


Evert, F.(1983) 82
Krabbe, P.(1984) 116
Payandeh, B.(1975) 145
Payandeh, B.(1974) 146
Salonius, P.O.; Fisher, R.A. and Mahendrappa, M.K.(1982) 156
Solomon, D.S.; Hosmer, R.A. and Hayslett, H.T.(1987) 167


SAMPLING\DATA ANALYSIS


Carmichael, A.J.(1968) 68
Gordon, A.M. and Morrow, L.D.(1979) 89
Heger, L. and Lowry, G.L.(1970) 103
Lowry, G.L.(1972) 122
Lowry, G.L. and Avard, P.M.(1967) 123
Lowry, G.L. and Avard, P.M.(1969) 123
Page, G.(1976) 143
Weetman, G.F. and Harland, R.(1964) 189

**BLACK SPRUCE cont.** **PAGE**

SITE INDEX

Benson, J.A.(1973) 57
Brown, K.M. and Clarke, F.R.(1987) 63
Evert, F. and Lowry, G.L.(1970) 82
Gagnon, J.D.(1964) 87
Heger, L. and Lowry, G.L.(1971) 103
Heger, L. and Lowry, G.L.(1970) 103
Horton, K.W. and Lees, J.C.(1961) 105
Jeglum, J.K.(1983) 108
Jeglum, J.K.(1974) 109
Lowry, G.L.(1975) 122
Lowry, G.L.(1972) 122
Lowry, G.L. and Avard, P.M.(1967) 123
Page, G.(1976) 143
Payandeh, B.(1986) 144
Payandeh, B.(1978) 145
Smith, V.G.(1983) 165
Watt, R.F. and Heinselman, M.L.(1965) 185

SPACING

Krabbe, P.(1984) 116
Lavigne, M.B.; Donnelly, J.G. and Nostrand, R.S. van(1987) 119
Nostrand, R.S. van(1975) 140
Payandeh, B.(1975) 145
Towill, W.D. and Siczkar, L.A.(1988) 178

THINNING/RELEASE CUTTING

Knowles, R.(1964) 115
Krabbe, P.(1984) 116
Lavigne, M.B.; Donnelly, J.G. and Nostrand, R.S. van(1987) 119
Meng, C.H.(1981) 130
Steneker, G.A.(1969) 169
Weetman, G.F.(1975) 186
Weetman, G.F.; Roberge, M.R. and Meng, C.H.(1980) 190

VOLUME/YIELD TABLES/EQUATIONS

Benson, J.A.(1973) 57
Brown, K.M. and Clarke, F.R.(1987) 63
Evert, F.(1983) 82
Evert, F. and Lowry, G.L.(1970) 82
Fox, G.D. and Kruse, G.W.(1939) 86
Gordon, A.M. and Morrow, L.D.(1979) 89

**BLACK SPRUCE cont.** **PAGE**

VOLUME/YIELD TABLES/EQUATIONS cont.


Hatcher, R.J.(1964) 102
Heger, L. and Lowry, G.L.(1971) 103
Heger, L. and Lowry, G.L.(1970) 103
Ker, M.F.(1976) 113
Lowry, G.L. and Avard, P.M.(1967) 123
Meng, C.H.(1981) 130
Morrison, I.K. and Foster, N.W.(1979) 135
Payandeh, B.(1978) 145
Perala, D.A.(1971) 146
Smith, V.G.(1983) 165
Towill, W.D. and Siczkar, L.A.(1988) 178
Vincent, A.B.(1962) 182
Weetman, G.F.(1975) 186
Weetman, G.F. and Harland, R.(1964) 189
Weetman, G.F.; Roberge, M.R. and Meng, C.H.(1980) 190
Woods, M.E. and Beckwith, A.F.(1987) 197


WOOD QUALITY


Anon.(1968) 43
Carmichael, A.J.(1968) 68
Carmichael, A.J.(n.d.) 69
Carmichael, A.J. and Ladell, J.L.(1967) 69
Dillon, M.J. and Ladell, J.L.(1966) 79
Hall, A.D.(1964) 96
Ladell, J.L.(1971) 118


OTHER


Hatcher, R.J.(1964) 102
Johnston, W.F.(1977) 111

**WHITE SPRUCE** **PAGE**

BIOMASS

Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) 37
Alemdag, I.S.(1982) 38
Harding, R.B.; Grigal, D.F. and White, E.H.(1985) 101

FERTILIZATION

Alban, D.H.; Perala, D.A. and Schlaegel, B.E.(1978) 37
Armson, K.A.(1966) 46
Foster, N.W. and Morrison, I.K.(1983) 85
Morrison, I.K. and Foster, N.W.(1979) 135
Phu, T.D. and Gagnon, J.D.(1975) 148
Swan, H.S.D.(1965) 175
Swan, H.S.D.(1962) 176
Weetman, G.F.(1966) 187

GENETICS

Horton, K.W. and Lees, J.C.(1961) 105
Stiell, W.M.(1986) 169

GROWTH AND DEVELOPMENT

Armson, K.A.(1966) 46
Behre, C.E.(n.d.) 49
Chang, C.I. and Kennedy, R.W.(1967) 72
Drinkwater, M.H.(1957) 80
Hale, J.D. and Fensom, K.G.(1931) 95
Hambly, E.S.L.(1980) 98
Harding, R.B.; Grigal, D.F. and White, E.H.(1985) 101
Heger, L.(1971) 102
Horton, K.W. and Lees, J.C.(1961) 105
MacArthur, J.D.(1959) 125
Mitchell, K.J.(1969) 132
Morrison, I.K. and Foster, N.W.(1979) 135
Phu, T.D. and Gagnon, J.D.(1975) 148
Solomon, D.S.; Hosmer, R.A. and Hayslett, H.T.(1987) 167
Stiell, W.M.(1986) 169
Stiell, W.M.(1955) 171
Weetman, G.F.(1966) 187
Willcocks, A.J.(1978) 193
Wood, J.E. and Dominy, S.W.J.(1985) 196

**WHITE SPRUCE cont.** **PAGE**

MODELLING

Krabbe, P.(1984) 116
Mitchell, K.J.(1969) 132
Solomon, D.S.; Hosmer, R.A. and Hayslett, H.T.(1987) 167

SAMPLING\DATA ANALYSIS

Day, M.W. and Rudolph, V.J.(1970) 78
Hale, J.D. and Fensom, K.G.(1931) 95

SITE INDEX

Berry, A.B.(1978) 58
Harding, R.B.; Grigal, D.F. and White, E.H.(1985) 101
Heger, L.(1971) 102
Horton, K.W. and Lees, J.C.(1961) 105
Stiell, W.M.(1986) 169
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1965) 193

SPACING

Arnup, R.W.(1987) 47
Bella, I.E.(1986) 50
Bella, I.E. and DeFrancheschi, J.P.(1974) 55
Krabbe, P.(1984) 116
Towill, W.D. and Siczkar, L.A.(1988) 178

THINNING/RELEASE CUTTING

Arnup, R.W.(1987) 47
Crossley, D.I.(1956) 75
Day, M.W. and Rudolph, V.J.(1974) 78
Day, M.W. and Rudolph, V.J.(1970) 78
Krabbe, P.(1984) 116
Stiell, W.M.(1970) 170

VOLUME/YIELD TABLES/EQUATIONS

Arnup, R.W.(1987) 47
Bella, I.E.(1986) 50
Berry, A.B.(1986) 58
Berry, A.B.(1978) 58
Claughton-Wallin, H. and McVicker, F.(n.d.) 73
Day, M.W. and Rudolph, V.J.(1974) 78

**WHITE SPRUCE cont.** **PAGE**

VOLUME/YIELD TABLES/EQUATIONS cont.

Drinkwater, M.H.(1957) 80
Hall, A.D.(1963) 96
Innes, M.R.(1967) 107
McMinn, R.G.(1986) 130
Morrison, I.K. and Foster, N.W.(1979) 135
Stiell, W.M.(1986) 169
Towill, W.D. and Siczkar, L.A.(1988) 178
Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G.(1965) 193
Willcocks, A.J.(1978) 193

WOOD QUALITY

Hall, A.D.(1963) 96

OTHER

Innes, M.R.(1967) 107
McMinn, R.G.(1986) 130

HERBICIDES

Crossley, D.I.(1956) 75

# ANNOTATED BIBLIOGRAPHY

Aaltonen, V.T. 1926. On the space arrangement of trees and root competition. J. For. 24(6): 627-644.

Synopsis: The paper describes the space arrangement existing between seedlings and mother trees. The distance of the trunks from each other is closely dependent on the quality of the site.

Ackerman, R.F. 1962. Density prediction in lodgepole pine stands by diameter growth analysis. For. Res. Br., Can. Dept. For., Ottawa, ON; Tech. Note No. 120, 15 pp.

A method is proposed for density prediction in lodgepole pine (Pinus contorta Dougl.) stands, utilizing diameter growth measurements obtained from single examination. One of two assumptions concerning mortality is necessary to apply the method: either a number of the largest trees are assumed to be mortality free or mortality is considered to occur at random over the prediction period.

To illustrate the technique the density at 21 and 32 years of age has been determined employing both assumptions for a stand which is now 155 years of age. The results suggest that the two hypotheses concerning mortality are not alternatives, but that the choice depends upon the length of the prediction period. If predictions are required over a very long period, the assumption of random mortality is applicable; for short periods, best results can be obtained by assuming that a small group of the largest trees are mortality free.

Density prediction over relatively short periods i.e. 40 years, utilizing a small group of the largest trees as a density index is believed to have the greatest application and will be particularly valuable in the construction of stand density yield tables for lodgepole pine.

Agee, J.K. and Biswell, H.H. 1970. Some effects of thinning and fertilization on ponderosa and understory vegetation. J. For. 68: 709-711.

Ponderosa pine (Pinus ponderosa Laws.) in northern California showed increased growth from both thinning and fertilizing. Trees were thinned in 1952-1953 and fertilizer was applied in 1958-1960. The greatest absolute increase in basal area of trees occurred on thinned-fertilized plots, followed by those on the fertilized-only plots, thinned-only plots and untreated plots. On a percentage-increase basis, the trees on the thinned-only plots showed a greater increase in basal area than did those on the fertilized-only plots. The understory vegetation increased with thinning of trees. Fertilizing increased understory most where the thinning was heaviest and very little where there was no thinning. The relationship between forest growth and pine management is discussed.

Alban, D.H. 1978. Growth of adjacent red and jack pine plantations in the Lake States. J. For. 76: 418-421.

In 25 pairs of adjacent plantations, mean annual increment of red pine (Pinus resinosa Ait.) was greater than that of jack pine (Pinus banksiana Lamb.) for 24 comparisons on a volume basis and for 20 on a weight basis. In no case did jack pine significantly outproduce red pine. Red pine mean annual increment averaged 29 cubic feet per acre greater than that of jack pine irrespective of site index, and this species differential is expected to increase as the stands grow older. The plantations averaged 36 years of age and represented a wide range of site indexes and soils throughout the northern Lake States.

Alban, D.H.; Perala, D.A. and Schlaegel, B.E. 1978. Biomass and nutrient distribution in aspen, pine, and spruce stands on the same soil type in Minnesota. Can. J. For. Res. 8: 290-299.

Vegetation and soils were sampled in adjacent 40 year old stands of red pine (Pinus resinosa Ait.), jack pine (Pinus banksiana Lamb.), white spruce (Picea glauca (Moench) Voss) and aspen (Populus tremuloides Michx., Populus grandidentata Michx.) on a very fine sandy-loam in north-central Minnesota. Total tree biomass was greatest for red pine followed by aspen, spruce and jack pine. Nutrient weights (N, P, K, Ca, Mg) in the trees were greatest in aspen followed generally by spruce, red pine, and jack pine. Particularly large proportions of biomass and nutrients were found in aspen bark and spruce foliage and branches. Understory biomass contributed up to 5.0% of the nutrients. Exchangeable Ca in the surface soil was much lower under aspen and spruce than under pines. No significant soil differences between species were detected below 36 cm. Harvesting the entire above ground portion of the tree would remove up to three times more nutrients from the site than harvesting only the bole.

Alban, D.H. and Watt, R.F. 1981. Fertilization of black spruce on poor site peatland in Minnesota. North Cent. For. Exp. Stn., USDA For. Serv. Res. Pap. NC-210, 10 pp.

As population pressures force forestry to the poorer sites, organic soils will become more important for forestry purposes in the United States. These soils are often fertilized to increase forest growth, and in some cases, to convert nonproductive to productive forests.

Black spruce (Picea mariana (Mill.) B.S.P.) growth has been enhanced by fertilization on both organic soils and mineral soils. The current study reports on the long term growth and nutrient response of black spruce and understory species to fertilization.

Alemdag, I.S. 1988. A ratio method for calculating stem volume to variable merchantable limits, and associated taper equations. For. Chron. 64: 18-26.

One method for estimating the volume of the merchantable portion of a tree stem is the volume ratio method. In this study the ratio used with this method was derived from another ratio expressed as ground-to-limit volume to total stem volume. Because of the latter ratio's strong correlation with the ratio of merchantable top diameter/breast height diameter and merchantable height/total tree height, several mathematical models were formed employing these variables for its estimation for red pine (Pinus resinosa Ait.) and sugar maple (Acer saccharum Marsh.). Among the models that were tested, the best for each variable was chosen by assessing its adequacy by the statistical measures of fit index and standard error of estimate. When checked against an independent set of data, these best models performed satisfactorily, with small overall biases. Furthermore, taper equations were derived from these ground-to-limit volume ratio equations.

Alemdag, I.S. 1984. Wood density variation of 28 tree species from Ontario. Petawawa Natl. For. Inst., Can. For. Serv., Chalk River, ON; Inf. Rep. PI-X-45, 12 pp.

The basic wood density at different heights along the stem and average basic wood density of stems were studied based on 1652 sample trees of 10 softwood and 18 hardwood species in Ontario. Some equation models were tested relating these variables to various tree characteristics. It was found that the relationships of disk and tree wood densities with measurable tree variables are very weak and developing reliable estimation equations are not easy. However, since variation on tree wood density was found to be small, average wood densities of each species can be used with confidence.

Alemdag, I.S. 1982. Aboveground dry matter of jack pine, black spruce, white spruce and balsam fir trees at two localities in Ontario. For. Chron. 58: 26-30.

Standard equations for aboveground ovendry mass of jack pine (Pinus banksiana Lamb.), black spruce (Picea mariana (Mill.) B.S.P.), white spruce (Picea glauca (Moench) Voss) and balsam fir (Abies balsamea (L.) Mill.) were developed for the components and for the whole tree of single stems grown in natural stands in Ontario. The relationships between the component and the stem wood ovendry masses and those between the ovendry and the green masses were determined. Distribution of ovendry mass within the stem wood of merchantable trees was established. Wood densities were calculated, and comparisons of stem wood ovendry mass were made between the equations developed here and those found in other reports.

Alemdag, I.S. and Stiell, W.M. 1982. Spacing and age effects on biomass production in red pine plantations. For. Chron. 58: 220-224.

Data and wood samples were collected from 155 trees in 16 high-survival, unthinned plantations of red pine (Pinus resinosa Ait.) near Chalk River, Ontario, aged 27 to 54 years, with initial spacings of from 1.52 x 1.52 m to 4.27 x 4.27 m. Following standard weighing and drying procedures, ovendry mass values of the whole tree and or their individual components were calculated, and regressions developed to relate mass values to stem dimensions of diameter breast height (d) and total height (h), and to determine what effects that initial spacing and stand age had on those relations.

Alexander, R.R. 1965. Growth of thinned young lodgepole pine in Colorado. J. For. 63: 429-433.

Two kinds of thinnings were made in lodgepole pine (Pinus contorta Dougl.). Uniform thinning reserved 630 trees per acre spaced an average of 8 feet apart. Crop-tree thinning released approximately 100 trees per acre, spaced an average 21 feet apart, by cutting openings 16 feet in diameter around each selected tree. Thinnings stimulated diameter growth of the best 100 trees under both treatments and of all trees on the uniformly thinned plots. Height growth was unchanged. Basal area increment was unaffected. Thinning initially reduced total cubic-foot volume increment, but after 8 years growth was the same on thinned and unthinned plots. Volume in pulpwood-sized trees was increased only by uniform thinning. The uniform method best meets the objectives of thinning. Earlier stumpage returns are indicated, and total stand growth will be redistributed on fewer but better quality stems.

Alexander, R.R. 1960. Thinning lodgepole pine in the Central Rocky Mountains. J. For. 58: 99-104.

Studies were initiated between 1924 and 1934 on four national forests in Colorado and Wyoming to determine spacing for thinning small lodgepole pine (Pinus contorta Dougl.). All plots, except one in each block, were thinned to different intensities. The remaining plot was left unthinned as a control.

Diameter growth in all age groups was stimulated by the intensities of thinning tested. It was greatest on the most heavily thinned plots. Basal area increment per acre was also stimulated in most treatments. The greatest basal area growth followed heavy thinning in the older and larger stands and light thinning in the younger stands.

Alexander, R.R. 1956. Two methods of thinning young lodgepole pine in the Central Rocky Mountains. J. For. 54: 99-102.

Synopsis: Two methods of thinning lodgepole pine (Pinus contorta Dougl.) on the Fraser Experimental Forest were examined: (1) the "single tree" method where all but 630 trees per acre were cut at a spacing of 8.5 feet apart and (2) the "crop tree" method where an opening 16 feet in diameter was cut around the best 100 trees of the stand. Eight years after treatment comparisons of average diameter growth were made between the thinning operations. Results showed that single-tree thinning had better initial growth. Since the cost of this treatment is high; crop-tree thinning is recommended.

Alexander, R.R. and Edminster, C.B. 1981. Management of lodgepole pine in even-aged stands in the Central Rocky Mountains. Rocky Mtn. For. Range Exp. Stn., USDA For. Serv., Fort Collins, CO; Res. Pap. RM-229, 11 pp.

Potential production of lodgepole pine (Pinus contorta Dougl.) in the central Rocky Mountains is simulated for various combinations of stand density, site quality, ages and thinning schedules. Such estimates are needed to project future development of stands managed in different ways for various uses.

Alexander, R.R.; Lotan, J.E.; Larson, J.M. and Volland, A.L. n.d. Lodgepole pine. USDA For. Serv. Handb. 445.

Synopsis: Lodgepole pine (Pinus contorta Dougl.) is one of the most widespread species in the Western United States. It has a remarkable ecological amplitude, growing in a variety of different environments. This chapter explains the stand conditions, seed production and habitat of lodgepole pine and its silvicultural importance.

Allison, J.H. 1952. Growth of unthinned jack pine stands at Cloquet. Univ. Minn., St. Paul, MN; Minn. For. Notes No. 1, 2 pp.

Synopsis: If the objective of production is pulpwood, a rotation of 50-60 years without thinning is adequate. Thinning is recommended for sawlog production when jack pine (Pinus banksiana Lamb.) stands, growing on medium sites, are about 40 yrs. old.

Alm, A.A.; Pflager, S.M. and Schantz-Hansen, R. 1979. Mechanized strip-thinning in jack pine reproduction. Can. J. For. Res. 9: 470-473.

Dense jack pine (Pinus banksiana Lamb.) reproduction resulting from a 1959 wildfire was mechanically thinned with a rotary cutter. Stocking and growth measurements taken immediately after thinning and after 9 years are presented. Results indicated that the nonselective thinning technique was ineffective in providing adequate stocking of desirable trees. A comparison of height and diameter growth on thinned areas with that on unthinned areas showed no satisfactory growth response resulting from the thinning.

Alm, A.A. and Schantz-Hansen, R. 1970. Mechanized thinning of dense post-fire jack pine regeneration. Univ. Minn., St. Paul, MN; Minn. For. Res. Notes. No. 220, 4 pp.

Synopsis: After a fire in a jack pine (Pinus banksiana Lamb.) stand, very dense reproduction occurred. To avoid growth stagnation, a mechanized thinning made by a rotary cutter in the 7-year-old stand was made. Immediately after thinning it was evident that the objective of increasing individual growing space was met but some tree damage and some distribution pattern problems may result.

Althen, F.W. von; Stiell, W.M. and Forster, R.B. 1978. Effects of four thinnings on the growth, yields and financial returns of a 62 year old red pine plantation. For. Chron. 54: 253-260.

Growth data for a 62-year old plantation of red pine (Pinus resinosa Ait.) at Rockland, Ontario, part of which was thinned four times between 1938 and 1972, and part of which was left unthinned, are presented for the two stand conditions, together with associated product yields and economic implications of alternative treatments. The investment in thinning, when based on historical costs and revenues, was attractive: the thinning program increased net present worth at each stage. When based on current costs and revenues, with no increase at an assumed inflation rate, the investment in thinning was less attractive, and it was not proved conclusively that the thinning program would be profitable. Financial growth peaked at a rotation age of approximately 50 years.

Anderson, E.A. 1951. Tracheid length variation in conifers as related to distance from pith. J. For. 49(1): 38-42.

A relationship between tracheid length and distance from pith was found in four coniferous trees: a white fir (Abies concolour (Gord. and Glend.) Lindl.), a noble fir (Abies procera Rehd.), and two Douglas fir (Pseudotsuga menziesii (Mirb.) Franco var menziesii). The relationship could be expressed mathematically for each tree without regard to age or level in the trunk, provided that the portion of the bole close to the ground was eliminated. The shortest tracheids were found near the pith; outward from the pith, tracheid length at first increased rapidly, then more slowly and with a tendency to level off.

Tracheids near the tree base were shorter than those at higher levels at points equidistant from the pith.

Springwood tracheids in white fir were found to be shorter than summerwood tracheids of the same annual ring.

Andison, D.; Roebbelen, P. and Beckwith, A.F. 1984. Initial thinning in a semi-mature white and red pine stand. OMNR, Maple, ON; For. Res. Note No. 35, 4 pp.

Management of natural white and red pine (Pinus strobus L. and Pinus resinosa Ait.) stands in the Algonquin region is of increasing importance, particularly because of the constant demand for high quality white pine sawlogs. Cutting practices a century ago removed only the best stems, and gave no thought to residual stand development. Today forest management strives for a high quality mature stand achieved through a series of improvement thinnings.

To enable comparison of various thinning methods combined with thinning intensities on a semi-mature stand, an experiment was established in 1952 in Stratton Township near Achray. This report describes the results 25 years after the initial thinning.

Anon. 1982. Stand density control and fertilization. Pp. 39-49 British Columbia For. Serv. year end (March 31, 1981) research review. 10 pp.

Synopsis: Increase in merchantable volume and wood quality can be achieved by manipulating stand density at the time of establishment and during the rotation and by improving tree nutrition by forest fertilization. This research review covers current studies being done. The studies presented are: spacing trials in the Prince George forest region; response of immature Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) and western hemlock (Tsuga heterophylla (Raf.) Sarg.) to thinning and fertilizer application; mechanical spacing in lodgepole pine (Pinus contorta Dougl.) stands; investigation of the causes of stagnation in lodgepole pine stands; tree injector system; fate of nitrogenous fertilizers applied to snow; and fertilizer screening trials in the interior of British Columbia.

Anon. 1982. Stand density control and fertilizer application. Pp. 50-57 British Columbia For. Serv. year end (March 31, 1981) research review. 8 pp.

Synopsis: This research review covers stand density control and fertilizer application. Reviews included are: spacing trials of lodgepole pine (Pinus contorta Dougl.); fertilizer related density control of lodgepole pine; herbicidal density control of lodgepole pine stands; tree injector system development and testing; fate of nitrogenous fertilizers applied to snow; fertilizing and thinning in interior forests; introducing nitrogen into a young PL stand: A comparison of methods; response of low-merchantability, repressed lodgepole pine trees to spacing and fertilization; foliar analysis research; and an investigation of Topophysis in the repression of lodgepole pine.

Anon. 1968. Annual report: wood quality unit. Ont. Res. Foundation, Ont. Dept. Lands For., Ontario, 35 pp.

The purpose of the studies on wood quality is to define those characteristics which contribute to superior quality in end-use products and to relate these characteristics to heritable and environmental factors. Three symposia on wood quality were held in 1959 to determine the future needs of the wood-using industries, particularly the pulp and paper industry. As a result, black spruce (Picea mariana (Mill.) B.S.P.) was selected as the most significat species for this study.

Armson, K.A. 1975. Growth response of jack pine to fertilization--A choice of parameters. Unpublished report. 17 pp.

The purpose of this paper is to describe briefly a conventional fertilizer trial in jack pine (Pinus banksiana Lamb.) and then discuss results on the basis of different measures used to assess growth. A basic discussion of the relevance of detailed tree stem analyses to silvicultural considerations presented by Shea and Armson (1972) forms a background to this present study. Further, complete detailed growth measurements for the stand in which the study area was located had been obtained previously (Shea, 1973).

Armson, K.A. 1973. Soil and plant analysis techniques as diagnostic criteria for evaluating fertilizer needs and treatment response. Northeast. For. Exp. Stn., USDA For. Serv., Upper Darby, PA; Gen. Tech. Rep. NE-3, 11 pp. (Reprinted from Forest Fertilization Symposium Proceedings, pages 155-166).

Use of soil and plant analysis techniques must take into account both stage of development and rate of growth of the tree crop and the environmental conditions under which the crop exists. The principles and relationships between plant growth, plant nutrients, and soil nutrients are illustrated. Soil and plant analyses have been used both comparatively and mathematically. The precautions necessary in sampling and use of chemical procedures applied to plots and soils are discussed briefly.

Armson, K.A. 1972. Fertilizer distribution and sampling techniques in the aerial fertilization of forests. Fac. For., Univ. Toronto, Toronto, ON; Tech. Rep. No. 11, 27 pp.

A study was made of the actual rates and distribution pattern of aerially applied urea fertilizer using nominal rates of 50 and 100 lb./ac. nitrogen. It was concluded that:

1. The variation in distribution at the 50 lb./ac. N rate was great enough to render such application unsuitable.
2. The amount of fertilizer monitored falling through the tree canopy (jack pine, Pinus banksiana) was similar to that monitored in open strips.
3. At nominal rates of 100 lb./ac. N, monitoring catchers of 1 square foot area were as suitable as those of 2 square feet area.
4. The estimated numbers of monitoring catchers needed to measure urea fertilizer at the 100 lb./ac. N rate was determined for various assumed levels of accuracy.
5. It was suggested that narrow rectangular monitoring plots using 10 catchers each be used to determine fertilizer distribution and tree growth plot locations.
6. Growth responses to fertilizer treatments are more realistic when related to both a response curve and the area distribution of fertilizer. A system of monitoring catchers and plots is recommended which will enable this to be accomplished.
7. The use of cacodylic acid to kill trees in lines, so that the dead red brown foliage would provide marker lines for the aircraft pilot was found feasible. It should be noted that although jack pine (Pinus banksiana Lamb.) and balsam fir (Abies balsamea (L.) Mill.) retain their dead foliage for a year or more, the foliage of spruces Picea falls after the tree's death.

Armson, K.A. 1968. Forest fertilization studies at the Englehart Management Unit. Can. Pulp Pap. Assoc., Woodl. Sec. Index. 2491 (F-2), 2 pp. (Reprint from Nov. 1968 Pulp Pap. Mag. Can.).

The main purpose of the studies being conducted in the Englehart Management Unit is to determine the forest productivities of representative soils.

The objective of this series of studies is to determine, experimentally, the means by which more fibre can be produced per acre per year with a view to management practices likely to exist in the near future.

These studies have concentrated on experimentally varying species and spacing and applications of various fertilizers and herbicides.

Armson, K.A. 1967. Forest fertilization: Progress and ... Can. For. Indus. Oct.: 42-43. (Title incomplete).

Most forest fertilization studies in Canada date from 1950. A dramatic increase in the number of studies undertaken can be expected in future years.

In this general review of forest fertilization, the author concentrates on shortcomings of the methodology of fertilization experiments and in reporting results. In trials involving fertilization at time of planting, lack of uniformity of planting stock-physically or genetically-has made results of questionable value. Meaningful specific data on soils treated and other experiment conditions is often not reported. The importance of fertilization time and manner of placement has not been given proper attention.

Armson, K.A. 1966. The growth and absorption of nutrients by fertilized and unfertilized white spruce seedlings. For. Chron. 42(2): 127-136.

A study was made of the effects of fertilizer additions on the growth and development of white spruce (Picea glauca (Moench) Voss) seedlings during their second growing season. In terms of dry weight increment, unfertilized trees grew for only two-thirds of the total growing season available as compared with fertilized trees. The relative growth rate curve for the fertilized trees was smooth with none of the abrupt changes which marked the curve for the unfertilized trees. The pattern of height growth was changed for seedlings which were fertilized. Nutrient uptake rates particularly for phosphorus were different under the two treatments and it is suggested that these differences were related to different patterns of height growth development and root extension.

Arney, J.D. 1985. A modeling strategy for the growth projection of managed stands. Can. J. For. Res. 15(3): 511-518.

Using a large data base of permanent research plots in coastal Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), a growth projection strategy is developed. The emphasis is on stratifying growth influences into potential and modifier functions for components of diameter and height growth within a stand table. Growth periods are defined as equal increments of top height through time. The model developed is an individual-tree, distance-independent, stand-projection model.

Arney, J.D. 1985. SPS: Stand projection system for mini- and micro-computers. J. For. 83(6): 378.

The Stand Projection System (SPS) was originally developed for coastal Douglas fir (Pseudotsuga menziesii (Mirb.) Franco). It is the only available model on the West Coast that provides yield projections and inventory updates for mixed species. Projections may be produced for natural stands or plantations for any initial stocking levels, site classes, thinning regimes and fertilization schedules. SPS is programmed in FORTRAN 77 for the Apple II+, IIe and IIc using 64k of memory and IBM PC compatibles using 256k of memory.

Arnup, R.W. 1987. 34 Year old tended vs. untended white spruce plantations, Edward Bonner Centre, Moonbeam analysis of TRIM data. North. For. Dev. Grp., OMNR, Timmins, ON; 78 pp.

Synopsis: In 1985, a Tree Ring Increment Measuring (TRIM) trial was initiated to examine growth and yield relationships on a 34 year old white spruce (Picea glauca (Moench) Voss) plantation. A 30m x 30m sample plot was outlined within each of the tended/untended areas. These trees were then destructively sampled for detailed TRIM analysis.

Included are growth and yield comparisons of the tended and untended areas, on a per tree and per hectare basis; comparisons with standard growth and yield tables; analysis of species/spacing relationsips; and correlation of growth with local climate.

The tended plantation showed significantly greater growth than the untended plantation. The results of this trial have significant implications with respect to rotation ages for fibre production in the Northern Region.

Axelsson, R. and Routledge, H. 1970. Cleaning young softwood stands: Academic exercise or practical solution. Pulp Pap. Mag. Can. 93-97.

The yield of desirable wood fibre can be significantly increased by tending young softwood stands through cleaning. With even age management and cleaning of young stands the landowner can cash in on the investment immediately by harvesting a volume per acre corresponding with the improved growth. High labour content and high costs in manual cleanings indicate that mechanization is needed. The Roanoke mower trials have shown the potential for cost reduction.

Baker, G. 1967. Estimating specific gravity of plantation-grown red pine. For. Prod. J. 17(8): 21-24.

Core-to-tree specific gravity relations were determined for trees in a 20 to 25-year-old red pine (Pinus resinosa Ait.) plantation. The proportion of variation in tree specific gravity associated with the regression on specific gravity of two cores was 41 percent.

Comparison of this regression equation with one derived from forest-grown trees indicates two separate and different populations. Application of the Wahlgren equation to plantation-grown red pine of the above age would give an estimate of tree specific gravity in error on the high side.

The vertical distribution pattern of specific gravity is not characteristic of mature forest-grown red pine. Instead of a decrease with height above the ground, there is an increase with increase in height after an initial drop in specific gravity at the 8-foot level.

Ballard, L.A. and Long, J.N. 1988. Influence of stand density on log quality of lodgepole pine. Can. J. For. Res. 18: 911-916.

We examined the relationship between stand density and stem quality characteristics for lodgepole pine (Pinus contorta Dougl.). The influence of initial stand density on end of rotation log quality was inferred by analyzing data from unmanaged, rotation-aged stands. Quality characteristics examined included first log branch diameters, taper, wood density, and the proportion of sapwood. After differences in diameter at breast height were accounted for, only branch size was strongly influenced by stand density. A strong negative exponential relationship was found between the mean of the five largest branches per first log and number of trees per hectare.

Barrett, J.D. and Kellogg, R.M. 1986. Lumber quality from second growth managed forests. Pp. 57-71 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

Increased use of rapidly grown Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) and southern pines decreases the average specific gravity of wood reaching the sawmills due to increased proportions of juvenile wood. Results of several studies relating juvenile wood and mature wood properties measured using small clear and structural size specimens are summarized. These show that the reductions in specific gravity can have a significant impact on lumber strength and stiffness properties.

Barse, R.G. and Laidly, P.R. 1980. Wood specific gravity of plantation red pine little affected by spacing. North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, MN; Res. Note. NC-251, 2 pp.

Red pine (Pinus resinosa Ait.) covers more than one million acres in Michigan, Minnesota, and Wisconsin. A large percentage of this acreage is plantations. Early thinnings of these plantations will yield pulpwood, posts, and some poles. And, specific gravity of this wood is an important quality factor affecting fibre yield, working and finishing qualities, and strength. The purpose of this note is to quantify the effect of spacing on wood specific gravity for red pine grown on a good site.

Bazeley, D.G. 1988. Growth rate, specific gravity and longitudinal shrinkage in 35 year old plantation-grown red pine (Pinus resinosa Ait.). H.B.Sc.For. thesis, Sch. For. Lakehead Univ., Thunder Bay, ON; 54 pp.

Growth rate (ring width), specific gravity, and longitudinal shrinkage of fifteen 35 year old plantation grown red pine (Pinus resinosa Ait.) were examined. The horizontal variations of each of these properties from pith to bark were evaluated. The period of juvenile wood formation was also determined. No correlation was established between growth rate and specific gravity. Specific gravity increased stem height. Specific gravity was found more closely related to the age of a tree than to its growth rate. Longitudinal shrinkage was highest close to the bark. An indirect correlation existed between longitudinal shrinkage and growth rate.

Behre, C.E. n.d. Change in form of red spruce after logging and of northern white pine after thinning. J. For. 805-810.

Change in form of trees left after logging is shown to depend upon the original character of the trees themselves. There will be no significant change in average form quotient unless the residual trees vary consistently above or below the general average at time of cutting. The amount of variation in form quotients of residual trees decreases for a number of years after partial cutting.

Bella, I.E. 1986. Spacing effects 20 years after planting three conifers in Manitoba. North. For. Cent., Can. For. Serv., Edmonton, AB; For. Manage. Note. No. 39, 11 pp.

Synopsis: A spacing study of three native conifers, jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.) and white spruce (Picea glauca (Moench) Voss) was established at Moodie, Manitoba, on flat, sandy, nutritionally poor soils with a fresh moisture regime. This note provides the latest growth information covering the first 20 years after planting. Red pine had the largest average dbh in terms of both total stand and largest trees/ha. Jack pine was behind red pine by approximately 15 percent. White spruce dbh growth was less than half that of the pines. Crown width showed a gradual increase with spacing for all three conifers. Results suggest optimum spacing ranges between 1.8 and 2.4 metres for both pines in order to achieve rapid tree growth and high future timber yields. Spruce is not recommended for planting on similar sites.

Bella, I.E. 1985. Pest damage incidence in natural and thinned lodgepole pine in Alberta. For. Chron. 61(3): 233-238.

Thinned stands of young lodgepole pine (Pinus contorta Dougl. var latifolia Engelm.) in west-central Alberta had a higher incidence of attack by common pest organisms than unthinned stands. Based on a sample of nearly 3000 potential crop trees (on 240 temporary plots) growing on 120 naturally regenerated cut blocks, the rate of attack in thinned vs. unthinned stands was 30% and 18% for western gall rust (Endocronartium harknessii (J.P. Moore) Y. Hiratsuta) and 25% and 16% for leader damage due to terminal weevil (Pissodes terminalis Hopp.) and pitch twig moth (Petrova spp.). Damage from other agents, including that from small mammals, was low and little affected by thinning.

Forest management implication of these results are discussed.

Bella, I.E. 1974. Growth response of young jack pine to mechanical strip thinning, Manitoba. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-102, 11 pp.

Operational strip thinning in relatively open 9-year-old jack pine (Pinus banksiana Lamb.) stands on sandy fresh sites in southeastern Manitoba resulted in a maximum increase of 40-50% in the following 10-year breast height diameter increment of larger trees close to the cut strips. No real difference in response was found between the two treatment intensities tried: one-way thinning (7-foot cleared swaths alternating with 10-foot-wide reserve strips), and two-way thinning (a second pass made with the chopper at right angles to the first, leaving groups of trees in blocks 10 feet by 10 feet). Strip thinning in denser stands on moist sites produced no significant results.

Unless marked improvements in growth occur in later years this type of strip thinning would be unjustified in similar stand, but it may be useful when followed by selective thinning along the two edges of the leave strips.

Bella, I.E. 1974. Thinning young lodgepole pine is faster with a brush saw. For. Chron. 50(4): 151-154.

The objectives of the study were to evaluate labour input required to thin young lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) stands of various densities with one of the better, currently available brush saws in: 1) undisturbed conditions and 2) stands that had previously received mechanical strip thinning.

Bella, I.E. 1972. Growth of young lodgepole pine after mechanical strip thinning in Alberta. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-23, 16 pp.

In 25 year old lodgepole pine (Pinus contorta var. latifolia Engelm.) stands in the foothills, strip thinning stimulated diameter increment, both at breast height and at ground level, of all trees in the dense portions of the stand within five years after treatment. Greatest absolute response in increment was among the larger trees while the small trees showed greater relative response. No significant thinning-response increment could be established among trees growing under relatively open stand conditions.

There was relatively small amounts of drum chopper damage to trees on strip borders and there is no evidence of increase in insect and disease activity.

Bella, I.E. 1971. A new competition model for individual trees. For. Sci. 17(3): 364-372.

The model represents mathematically competitive interaction between individual trees. It consists of two basic components: (1) the influence zone of each tree (which is a function of its size) and (2) the amount and nature of interaction (which depends on the distance between and relative size of the competing tree and its competitors and also on a power of relative tree sizes). Optimum model parameters were obtained by iterative procedures on a computer, combined with regression analyses for pure, even-aged, fully stocked stands of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.), and aspen (Populus tremuloides Michx.) and for an even-aged stand of Eucalyptus spp. growing at a range of stand densities. The model satisfactorily described competition effect for the five stands studied and accounted for a greater portion of variation in tree growth than some of the earlier competition indices.

Bella, I.E. 1968. Jack pine yield tables for southeastern Manitoba. Dept. Fish. For., For. Br., Ottawa, ON; Publ. No. 1207, 15 pp.

Jack pine (Pinus banksiana Lamb.) yield tables based on 365 permanent sample plot measurements are presented for the major jack pine site types in southeastern Manitoba. Total volume curves are constructed by fitting a modified version of a logarithmic growth function to the data. Merchantable volumes are obtained by using ratios. Sites are described in terms of landform features, soil characteristics and vegetation.

Bella, I.E. 1967. Development of jack pine and scots pine in the Spruce Woods Forest Reserve, Manitoba. Can. Dept. For. Rural Dev., For. Br., Winnipeg, MB; Dept. Publ. No. 1171, 15 pp.

This report presents data on the development to 1964 of three jack pine (Pinus banksiana Lamb.) and three Scots pine (Pinus sylvestris L.) plantations set out in the Spruce Woods Forest Reserve, Manitoba, in 1916. The data were obtained from six permanent sample plots, established in the plantations in 1952.

Results have shown that goor growth and full stocking can be achieved by both jack pine and Scots pine. However, Scots pine has maintained a significantly greater diameter increment and about 25 per cent higher total basal area and volume production than jack pine. No significant difference was found between dominant heights of the two species.

Thinning has resulted in higher net increment and lower mortality for both species.

Bella, I.E. 1966. Strip thinning jack pine thickets with a "drum chopper" in Manitoba. For. Res. Lab., Can. Dept. For., Winnipeg, MB; Inf. Rep. MS-X-3, 9 pp.

In 1963, a large scale program of mechanical strip thinning was begun in young jack pine (Pinus banksiana Lamb.) stands in southeastern Manitoba using a Fleco Drum Chopper and by 1965, some 5,200 acres had been treated. A study was initiated in the spring of 1964 to determine: (1) the influence of strip thinning on stand and tree development, and (2) the extent of damage to residual stems. The results are presented for two growing seasons after treatment.

These preliminary results suggest that mechanical strip thinning may be an effective and safe method to reduce density and maintain rapid tree growth in young jack pine stands.

Bella, I.E. and DeFrancheschi, J.P. 1982. Growth of lodgepole pine after mechanical strip thinning in Alberta: 15-year results. For. Chron. 58(3): 131-135.

An operational thinning in a 25 year old lodgepole pine (Pinus contorta Dougl. var latifolia Engelm.) stand in Alberta resulted in nearly a 50% increase in diameter at breast height (dbh) and height increment in the last 5 years. Initial stand density had no effect on dbh increment beyond that of initial tree size. The release effect extended throughout the narrow (around 1.5 m) leave strips. Mortality continued to occur at about the same rate in both treated and untreated plots, thus reducing the need for follow-up selective thinning. Although the treated area had much lower stand volumes, it has a faster growth rate and may catch up or even surpass the untreated area in merchantable yield at harvest.

Bella, I.E. and DeFrancheschi, J.P. 1980. Spacing effects 15 years after planting three conifers in Manitoba. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-223, 10 pp.

Jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.), and white spruce (Picea glauca (Moench) Voss) were planted at 1.2-, 1.8-, 2.4-, and 3.0-m spacings in 11 X 11 matrices with four replications in the Sandilands Forest Reserve in Manitoba. Measurements were taken in 1978, 16 growing seasons after planting.

Diameter increment in terms of basal area was over 100% greater for wide than for narrow spacings, which gave rise to substantial differences in average diameter. At wide spacing, red pine surpassed jack pine by a small amount. Height growth was reduced with increasing spacing in jack pine but was unaffected in red pine. The average height of white spruce was less than half that of the pines. Jack pine developed poor tree form and heavy branches at wide spacings, while red pine showed little adverse effect. Mortality was low. Stand productivity - whether in basal area, volume, or biomass - was highest at the closest spacing, but continued faster growth at wide spacing means that the difference be reduced or even eliminated by rotation age. Recommendations are given on spacing and species selection for future planting of conifers in southeastern Manitoba.

Bella, I.E. and DeFrancheschi, J.P. 1977. Young lodgepole pine responds to strip thinning, but... North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-192, 10 pp.

Operational strip thinning (with drum choppers) in a 25 year old lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) stand in south west Alberta resulted in an increase in basal-area growth of over 60% among the largest leave trees (potential crop) by the tenth year after treatment. Relative response to thinning was greatest where the trees were small, that is, on plots with initially high densities. Tree mortality, which was greater with higher stand densities, was unaffected by treatment in the same period.

Recommendations are given about similar thinning operations.

Bella, I.E. and DeFrancheschi, J.P. 1974. Analysis of jack pine thinning experiments, Manitoba and Saskatchewan. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Publ. No. 1338, 21 pp.

Growth data from six jack pine (Pinus banksiana Lamb.) thinning experiments showed generally increased diameter increment after treatment. The stands treated were between 10 and 60 years old and covered site conditions ranging from poor to good.

Improvement in yield on poor sites, if any, was minor. On average sites, precommercial thinning of initially dense stands increased cordwood yields up to 25% and nearly doubled board foot yields by age 60. On good sites, the removal of one-third of total basal area and cordwood volume by low thinning paid for itself, while the final yield 20 years later would reach, or even surpass, that of the unthinned stands. A crown thinning would generally reduce final yield in jack pine. Initial density (in number of trees) had an important effect on stand development: trees in open portions of stands on average sites had greater final yield, even if unthinned, than initially denser portions that were thinned at age 19. Therefore, jack pine stands should be precommercially thinned when they are very young, preferably under 10 years of age.

Bella, I.E. and DeFrancheschi, J.P. 1974. Commercial thinning improves growth of jack pine. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-112, 23 pp.

Jack pine (Pinus banksiana Lamb.) stands on good sites showed improved tree and stand growth following commercial low and crown thinning at age 40. Data 15 years after thinning suggest that gross pulpwood and sawlog yields (thinning plus final yield) will be greater in treated stands.

Growth response to crown thinning occurred later than response to low thinning, but its effect was of longer duration. Therefore, on good sites, a combination of low and crown thinning which removes up to 30-35% of basal area at a stand age of about 40 years may be advantageous because it reduces thinning costs, improves yield, and lowers harvesting and processing costs because of increased tree size.

Bella, I.E. and DeFrancheschi, J.P. 1974. Early results of spacing studies of three indigenous conifers in Manitoba. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-113, 10 pp.

Jack pine, red pine and white spruce (Pinus banksiana Lamb., Pinus resinosa Ait., Picea glauca (Moench) Voss) were planted at 4-, 6-, 8-, and 10-ft (1.3-, 2.0-, 2.6-, and 3.3-m) spacings in an 11 x 11 matrix with four replications on nutritionally poor, sandy fresh sites in the Sandilands Forest Reserve. Eleven growing seasons after planting: (1) There was no significant spacing effect on height growth of any of the species; (2) Diameter growth of jack pine was best at the two intermediate spacings, but diameter growth of red pine was not affected; (3) There was an increase in tree form at wider spacing in jack pine; (4) Jack pine grew over 30% faster in diameter and height than red pine and might be favoured for fibre production, while red pine retained better tree form even at the widest spacing, and thus seems more suited for sawlog production in the absence of thinning, provided that current growth trends continue.

Bendtsen, B.A. 1978. Properties of wood from improved and intensively managed trees. For. Prod. J. 28(10): 61-72.

A limited review of the literature was conducted concerning wood properties of improved trees grown under intensive management. It is concluded that differences between wood properties of trees from the natural and "manmade" forests are associated with the short-rotation and resulting high proportion of juvenile wood in the harvest of the improved trees. Properties of juvenile wood of conifers and hardwoods and problems encountered in processing and utilizing juvenile wood in solid wood products are discussed. Insights are offered concerning the rapidly changing forest resource and its implication in the solid wood industry, particularly lumber.

Bennett, W. 1986. What do you need? What do you have? Pp. 48-49 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

This talk is about communication and cooperation between converters of logs and those who grow them--and the lack thereof.

Benson, J.A. 1973. Black spruce in Saskatchewan. Sask. Dept. Tourism Renew. Resour. Tech. Bull. No. 7, 68 pp.

Synopsis: Growth and yield of well stocked black spruce (Picea mariana (Mill.) B.S.P.) stands in Saskatchewan is estimated, and black spruce forests are described.

Benson, R.E. and Strong, R.A. 1977. Wood product potential in mature lodgepole pine stands, Bitterroot National Forest. Intermt. For. Range Exp. Stn., USDA For. Serv., Ogden, UT; Res. Pap. INT-194, 16 pp.

An attempt was made to identify and evaluate alternatives for expanding forest-based industry in the Bitterroot Valley. Fieldwork was completed in mature lodgepole pine (Pinus contorta Dougl. ex D. Don) stands to provide more detailed inventories and information on the utilization potential, particularly for the dead, down, and small-size material that frequently remains as residue after logging.

This report summarizes the utilization potential of mature lodgepole pine stands, including this "residual material". Comprehensive data on the timber resource for other forest types are contained in the various summaries and reports compiled by the Bitterroot National Forest and the Regional Office Timber Management Staffs.

Benzie, J.W. 1977. Manager's handbook for jack pine in the North Central States. North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, MN; Gen. Tech. Rep. NC-32, 18 pp.

Provides a key for the resource manager to use in choosing silvicultural practices for the management of jack pine (Pinus banksiana Lamb.). Control of stand composition, growth, and stand establishment for timber production, water, wildlife, and recreation are discussed.

Bernier, B.; Brazeau, M. and Winget, C.H. 1972. Gaseous loss of ammonia following urea application in a balsam fir forest. Can. J. For. Res. 2: 59-62.

Nitrogen losses through ammonia volatilization increased with increasing rates of application and were 6.8% of 112 kg urea-N/ha after 10 days in a balsam fir (Abies balsamea (L.) Mill.) forest. Initial humus moisture content within the limits studied affected volatilization rates in the first days but had little effect on overall losses. A discontinuous ammonia-trapping technique for field use is discussed.

Berry, A.B. 1986. Volume tables and taper curves for plantation white spruce. Petawawa For. Exp. Stn., Can. For. Serv., Chalk River, ON; Inf. Rep. PS-X-1, 20 pp. (Proj. P-258).

The purpose of this paper is to produce volume tables, based on accepted standards of utilization, from taper curves constructed for young plantation-grown white spruce (Picea glauca (Moench) Voss). Equations are presented along with volume tables and taper curves.

Berry, A.B. 1984. Volume and biomass yield tables for unthinned red pine plantations at the Petawawa National Forestry Institute. Petawawa Natl. For. Inst., Can. For. Serv., Chalk River, ON; Inf. Rep. PI-X-32, 27 pp.

Yield tables for high survival unthinned red pine (Pinus resinosa Ait.) plantations were updated, revised, and extended from 50 to 60 years. For the first time they show data on biomass. Tables present data from 20 to 60 years from planting, by 5-year age classes, for eight spacings and five site index classes. Each table shows the dominant height, average height, number of trees, mean dbh, total basal area, total volume, merchantable volume, and biomass of merchantable stem including bark.

Berry, A.B. 1978. Metric yield tables based on site class and spacing for white spruce plantations at the Petawawa Forest Experiment Station. Petawawa For. Exp. Stn., Can. For. Serv., Chalk River, ON; Inf. Rep. PS-X-70, 14 pp.

Yield tables for high survival unthinned white spruce (Picea glauca (Moench) Voss) plantations were updated and revised to present the data in metric units. Tables present the data from 20 to 50 years from planting, by 5-year age classes, for six planted spacings and four site index classes. Each table shows the number of trees, basal area, total volume, and merchantable volume per hectare and the mean dbh for each age and spacing. Site index curves are also presented.

Berry, A.B. 1969. Height growth reduced following heavy thinning in a young red pine plantation. Bi-M. Res. Notes. 25(4): 37-38.

Synopsis: In 1962 studies were initiated in a large spacing trial of red pine (Pinus resinosa Ait.). The study involved thinning a plantation from an original planted spacing of 7 x 7 feet to a spacing of 14 x 14 feet by systematically removing every second row and every second tree in the intervening rows. Early results showed a drop in height growth for 3 years, then a resumption to normal growth patterns.

Berry, A.B. 1969. Spacing of red pine affects upper stem and crown growth. Bi-M. Res. Notes. 26(5): 50-51.

Synopsis: Tree dimensions vary directly with the available growing space. The wider the spacing between trees the greater will be the diameter at breast height, total stem volume, crown length and crown width of the individual trees.

A study was undertaken in 1969 to determine if, in young plantation red pine (Pinus resinosa Ait.), spacing did actually influence the development of the "free growing" top. Spacing used in study areas were 4 x 4, 6 x 6, 8 x 8, 10 x 10, and 14 x 14 feet.

Results show a definite tendency for the more closely spaced trees to have smaller stem diameters and narrower crowns in the free growing top than occur in corresponding whorls of trees at wider spacings.

Bickford, C.A. 1957. Stocking, normality, and measurement of stand density. J. For. 55: 99-104.

At the 1947 meeting of the Society of American Foresters, the Division of Silviculture established a Committee on Technical Procedures and Standards. Subcommittees were set up to supplement this work, including one on stocking. This is the report of the Committee on Stocking. The objectives of the report were to: 1) examine existing concepts of stocking; 2) review the various measures of density and stocking; 3) appraise the usefulness of each in current practice; 4) urge the research needed to fully define and describe the basic relations of stocking in stand development; and 5) encourage the development and use of better measures of stocking and stand density.

Biltonen, F.E.; Hillstrom, W.A.; Steinhilb, H.M. and Godman, R.M. 1979. Mechanized thinning of northern hardwood pole stands: methods and economics. North Cent. For. Exp. Stn., USDA For. Serv. Res. Pap. NC-137, 17 pp.

The purpose of this study was to determine the cost of thinning, chipping, and transporting second-growth, northern hardwood pole stands using a completely mechanized system.

The specific objectives were: (1) To determine ways of increasing the productivity of equipment for thinning that is normally used for clearcutting and whole-tree chipping. (2) To evaluate the damage to the residual stand caused by the harvesting equipment. (3) To determine the best thinning method. (4) To determine the cost of mechanized thinning in a northern hardwood stand when the cut material is recovered and utilized.

Blackerby, L.H., Assoc. Ed. 1969. Fertilization: Forest fertilization will help meet future wood supply needs. Reprinted from Sept., Oct., and Nov. 1969 issues of Forest Industries. 20 pp.

Synopsis: This manuscript is the first part of a series on forest fertilization in North America. This section is concerned with the introduction, current progress and future needs of forest fertilization in various areas on North America. Research and development are explained in relation to stumpage value, effects of fertilization on water quality, and recreation and wildlife.

Part two of the series covers the results and potential gains in fertilizer use, examples are given using Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) growth.

Part three of the series refers to the methods of fertilization and trials being tested. Application techniques are discussed with relation to site, and type of fertilizer being used. Results from some of these applications are presented.

Boldt, C.E. 1969. Jack pine plantations in the Nebraska sandhills. J. For. 67: 96-100.

Describes the development of a jack pine (Pinus banksiana Lamb.) plantation in the Nebraska sandhills for 48 years, including response to thinning at age 12. Growth was found to be equal to stands on similar sites in the species' native range in the Lake States.

Bolghari, H.A. 1976. Estimation de la production de jeunes plantations de pin rouge et de pin gris du sud du Quebec. Can. J. For. Res. 6: 478-486. (French article, English abstract).

Multiple regression equations have been developed to predict yield from young red pine (Pinus resinosa Ait.) and jack pine (Pinus banksiana Lamb.) plantations. Data from 446 sample plots representing young red pine and jack pine stands located on the south shore of the St. Lawrence River between Quebec and Montreal were analyzed. The red pine plantation yielded more than the jack pine. However, in plantation both species yield more than in natural stands. Taking into account the age and spacing of the sampled plantations, the equation obtained can provide information on yield of red pine and jack pine stands the maximum spacing of which is 3 X 3 m, up to the age of 45 and 35 years respectively. The equations will allow the construction of preliminary yield tables for both species.

Bolghari, H.A. and Bertrand, V. 1984. Preliminary yield tables for the main coniferous species planted in central southern Quebec. Min. de l'Energie et des Ress., Serv. de la Rech., Ter. et For., Gouv. du Quebec Mem. Rech. For. No. 79, 392 pp. (Tables preliminaires de production des principales essences resineuses plantees dans la partie centrale du sud du Quebec. French article, English abstract).

Constructed to show net and gross production from young plantations of red, jack, white and Scots pines, white and Norway spruces, as well as American, European, and Japanese larches. Tables of two kinds: net yield (excluding losses through regular mortality) and gross yield (including these losses) taking into account initial spacing on the one hand, and net and gross yields in conditions of full stocking (normal density) on the other hand. Also, for each species, site index curves are presented, anamorphic for white spruce and white pine, and polymorphic for the other species. Multiple regression equations to compute the actual volume as a function of basal area and dominant height or mean diameter are given. Due to a limited number of samples for the older plantations, it has been difficult to precisely determine rotation ages.

Braathe, P. 1957. Thinnings in even-aged stands: A summary of European literature. Fac. For., Univ. New Brunswick, Fredericton, NK; 92 pp.

Thinnings in even-aged forests have been carried out in many European countries for more than one hundred years, and research on the effect of thinnings has been conducted in Central Europe for 85 years.

In this summary of European literature on thinnings the aim, briefly, is to give the main results up to the present. In this, emphasis is put on the most recent literature, especially reports on research.

The present summary deals primarily with Norway spruce (Picea abies L. Karst.) and beech (Fagus sylvatica L.).

Results from Scots pine (Pinus sylvestris L.) and European fir (Abies pectinata) are also briefly referred to.

Bramble, W.C.; Cope, H.N. and Chisman, H.H. 1949. Influence of spacing on growth of red pine in plantations. J. For. 47(9): 726-732.

The spacing at which trees are planted appears to be one of the more important factors influencing their early growth rate and development. Although the general nature of the effects of various spacings is fairly well understood, the magnitude of those effects is not.

The growth and development of red pine (Pinus resinosa Ait.) spaced 5 by 5, 6 by 6, 6 by 8, and 10 by 10 feet in plantations have been studied over a 25-year period in central Pennsylvania.

Diameter growth of the two widest spacings has greatly exceeded that of the 5 by 5 and 6 by 6 spacing. A difference of 2.7 inches in average d.b.h. of all trees existed in favour of the 10 by 10 spacing over that of the 6 by 6 spacing at 25 years; a difference of 2.13 inches d.b.h. also existed in favour of the crop trees of the 10 by 10 plot.

Up to 25 years of age there were no signs of deterioration in the rapidly growing stands with wide spacings.

Brix, H. 1976. Biological insights gained from fertilization - thinning trials at Shawnigan Lake, B.C. Presented at Can. Inst. For. Workshop on Juvenile Spacing in Western Canada. 19 pp.

Synopsis: In silvicultural practices such as site preparation, forest fertilization and juvenile spacing, the aim is to create an environment favourable for tree growth. It is often found that a particular practice may be beneficial in some cases but not in others; however, we are unable to explain why this is so.

Herein is briefly discussed, some of the important environmental changes brought about by thinning and some of their effects on physiology and growth of trees. The Shawnigan Lake experiments will form the basis for this discussion. Thinning was done in a 24-year-old douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) stand and it, therefore, cannot be classified as juvenile spacing.

Brown, K.M. and Clarke, F.R. 1987. Growth and yield of young, managed, jack pine and black spruce in northwestern and north central Ontario. Sch. For., Lakehead Univ., Thunder Bay, ON; Final Rep. 211 pp.

This report documents a 3-year study that was aimed at providing growth and yield information for the young, managed stands of jack pine (Pinus banksiana Lamb.) and black spruce (Picea mariana (Mill.) B.S.P.) in Northwestern and North Central Ontario. Briefly, the study method was to visit and measure a random sample of young, managed stands in the study region. The sample was divided between stands that were being managed for each of the 2 study species: jack pine and black spruce. Within each sample stand, three 50 $m^2$ circular plots were located at random. At each plot, the stems of all trees were sectioned for stem analysis.

The stem analysis sections were measured, and the resulting data were analyzed to estimate the volume of every tree at 2 points in time: the time of harvest, and 3 years prior to harvest. Individual tree volume estimates were used to reconstruct the total volume on each plot by species and age category at the same 2 points in time. Finally, the 3-year periodic volume increment was calculated for each plot by species/age-class category.

In addition to the periodic volume increment data just described, several other plots attributes were documented: Stem analysis data were analyzed to determine the age at which each plot reached the 1- and 2-metre total height criteria required to meet free-to-grow standard; measurements on the physical attributes of each study location were taken; and information in the silvicultural treatment of the present stand was collected. Together, these data form the basis for the growth and yield and free-to-grow analyses which were the final products of this study.

Brunig, E.F. von and Schneider, T.W. 1978. A discussion of J. Weihe's paper 'The correlation between stem diameter/height ratio, normal form factor and crown length ratio in Norway spruce stands'. Forstarchiv 49(1): 12-13. (German article. Zu J. Weihe 'Die Wechselbeziehung zwischen Grundbreite (d:h), echter Formzahl und Kronenanteil in Fichtenbeständen' im Forstarchiv 10/77. Abstracted from For. Abst. 39(8): 3286).

Preliminary results from 20- to 110-yr-old pine (Pinus sylvestris L.) stands in W. Germany indicate, in contrast to Weihe's results, a significant (negative) correlation between stem ht./diam. [d.b.h.] ratio (h/d), and crown length ratio. The discrepancy between the results is attributed to the narrower range of h/d values studied by Weihe (75-108%, vs. 36-162%). Calculations suggest that crown dimensions in these pine stands are determined chiefly by the initial number of trees, and by the time and extent of thinning. Thus late thinning would have little effect on crown growth (or on h/d). Further studies are recommended on the relationships between individual tree form characters and stand and environmental factors.

Bublitz, W.J. 1971. Kraft pulping quality of thinnings from young Douglas-fir. TAPPI 54(6): 928-932.

A study has been made of the kraft pulping characteristics of thinnings from young Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) trees. The yields and permanganate numbers of the thinnings pulps were within commercially acceptable limits. The strength properties of the thinnings pulps were somewhat influenced by the relatively high percentage of juvenile wood, but as a whole they were comparable to those of commercial Douglas fir kraft pulp from more mature trees. The presence of bark in the twigs generally reduces the pulp yield and strength, but the loss of economic value in yield and quality must be related to the cost of debarking these small trees in order to evaluate properly the role of thinnings in the raw material picture of pulpwood.

Buckman, R.E. 1964. Twenty-two-year results of a precommercial thinning experiment in jack pine. Lake States For. Exp. Stn., USDA For. Serv., St. Paul, MN; Res. Note LS-46, 2 pp.

Synopsis: An experiment in precommercial thinning of jack pine (Pinus banksiana Lamb.) was initiated in 1941 with spacing treatments of 4 x 4, 6 x 6, and 8 x 8 feet. Results showed that differences in stand and tree characteristics were not significant and that the spacings used in this study make no practical difference in taper in the first 20 feet of stand height. Two tables showing stand characteristics at the various spacings are included.

Buijtenen, J.P. van. 1969. Controlling wood properties by forest management. Tappi 52(2): 257-259.

This paper analyzes forestry operations in terms of their effect on wood quality. Major factors are choice of site and species, genetic improvement, silvicultural practices, modern harvesting methods, and pulpwood storage. Through these factors a great deal of control can be exercised over the quality of raw material that reaches the pulp mill. Greatest opportunities to produce more uniform pulpwood that meets specific quality standards exist in: utilizing particular portions of the stem for specific products; developing varieties of trees capable of responding to intensive management; and developing management practices capable of utilizing the full potential of these improved varieties.

Bulger, D. 1987. Fertilization: A management technique for intensive forest management. OMNR, On Line to North. For. Dev., 3 pp.

Synopsis: In 1968, a 49-year-old jack pine (Pinus banksiana Lamb.) stand was treated with urea fertilizer sufficient enough to provide nitrogen at rates of 56 kg/ha and 112 kg/ha. The purpose of this study was to determine the amount and form of any growth response to an application of nitrogen fertilizer. Growth response to the fertilization, as measured by volume increment, was determined using destructive sample analysis. Results, which were limited by small sample size, indicated that if fertilizer is applied at a minimum rate of 112 kg/ha nitrogen, a 20% increase in volume growth can be expected for a 5-year period following fertilization. However, high cost of fertilizers and the variability in the results of many previous studies suggest that fertilization is not a viable forest management option for accelerating the growth of existing jack pine (Pinus banksiana Lamb.) stands.

Bulger, W.D. 1987. Nelder spacing trials for jack pine: a small sample analysis. North. For. Dev. Grp., OMNR, Timmins, ON; Intr. Rep. , 34 pp.

The purpose of this report is to present the findings of a small sample analysis examining the effects of initial spacing on jack pine (Pinus banksiana Lamb.). In particular, the analysis examines the nature and strength of the following relationships: a) spacing with height growth; b) spacing with volume growth; c) spacing with stem form; d) spacing with crown development; e) spacing with mortality.

Three consecutive 24-tree radii (jack pine stock) of a Nelder spacing plot were destructively sampled and analyzed using the TRIM growth layer analysis system. Analysis indicates that spacing has a strong influence on volume growth, stem form, crown growth and mortality but little influence on height growth.

Results indicate that for this site, an appropriate initial spacing for production of sawlogs is in a range between 1.8 m and 2.2 m.

Burger, D. 1972. Forest site classification in Canada. J. Assoc. For. Site Sci. For. Tree Breed. 21: 20-36.

Synopsis: This review is concerned with the development and present status of forest site classification in Canada. Topics covered include: studies emphasizing ground vegetation types; and studies emphasizing physiography: A. The Ontario classification system: 1.Taxonomic classification, 2. Site mapping, 3. Site evaluation; other studies emphasizing physiography: 1. Taxonomic classification, 2. Site mapping, 3. Site evaluation, 4. Canada Land Inventory, a national land evaluation; and agricultural soil surveys.

Burschel, P. 1974. Modern ideas on thinning, exemplified by models of spruce stands. Forstarchiv 45(2/3): 21-42. (German article, English summary; Pages 29-42 missing. Abstracted from For. Abst. 1974 35(10):6077; Die Durchforstung in heutiger Sicht, Dargesteilt an Modellen des Fichtenreinbestandes).

This paper discusses the development of volume and financial yields of pure spruce stands on the basis of simulated models assuming a top height of 32 m, a 100-year rotation, three initial spacings (3 000, 5 000 or 10 000 plants/ha) and three thinning schedules: (a) traditional moderate thinning leading to 575 final crop trees; (b) a 'differentiated thinning' concentrated chiefly in the ages <35 years and leading to a similar number of crop trees; and (c) a stem number thinning schedule based on stem-number/top-height relations, with heavy stem number reductions in the second half of the rotation, the final number of 400 crop trees being reached at stand height 25-28 m. It is concluded that wide initial spacings, and thinnings of the (b) and (c) type are likely to lead to the highest volume and/or financial yields and that such treatments are acceptable from the point of view of stand stability and wood quality.

Calvert, R.F. and Armson, K.A. 1975. The growth response of young jack pine to nitrogen and phosphorus. Can. J. For. Res. 5: 529-538.

N as urea at rates of 0 and 100 kg/ha and P as triple superphosphate at 0, 200, and 400 kg/ha were applied to 5-year-old jack pine (Pinus banksiana Lamb.) growing in a well-drained, sandy, orthic humo-ferric podzol. The urea was broadcast, but two types of application were made for the P: it was either broadcast or placed in the soil about each tree. One half of each plot received herbicide treatment. Tree measurements and foliage sampling were made later in the year of treatment and also during the next year. Fertilizer treatments increased the needle weight of foliage produced in the treatment year but did not affect height. Simazine-paraquat herbicide reduced height growth the year after treatment. From the changes in nutrient concentrations it is argued that K is a most likely limiting nutrient.

Carmean, W.H. and Lenthall, D.J. 1988. Height growth and site index curves for jack pine in north central Ontario. Typewritten draft for submission to Can. J. For. Res. Vol. 18. 40 pp.

Height growth patterns for jack pine (Pinus banksiana Lamb.) were studied using stem analyses from dominant and codominant trees on 141 plots in north central Ontario. A site index prediction equation was computed that expressed site index as a function of age and tree height.

Major results of the study are: 1) height growth curves based on breast height age were more precise than curves based on total age; 2) polymorphic height growth patterns were related to level of site index, becoming more curvilinear as site index increased; 3) average height growth patterns were similar for jack pine growing on four glacial soil groups; and 4) height growth patterns for ages less than 50 years were very similar to patterns of commonly used jack pine site curves for Ontario.

Carmichael, A.J. 1968. Black spruce wood quality. 1. The prediction of specific gravity. Pp. 223-225 in Spruce Symposium Proceedings of the Eleventh Meeting of the Committee on Tree Breeding in Canada. (Part 2).

Synopsis: There is general agreement that two radial increment cores, taken at right angles from breast height, will relate adequately to mean tree specific gravity. This paper documents a study conducted on black spruce (Picea mariana (Mill.) B.S.P.) to test this general agreement. The data suggest that further sampling is necessary to verify the relationships observed and to provide regression equations for converting diameter strip specific gravity to weighted tree specific gravity.

Carmichael, A.J. n.d. Quality wood program. Pp. 3-9 Appears to be photocopy of a Proceedings paper.

The purpose of the studies on wood quality is to define those characteristics which contribute to superior quality in end-use products and to relate these characteristics to heritable and environmental factors. In 1963, the Advisory Committee for the Wood Quality Program accepted black spruce (Picea mariana (Mill.) B.S.P.) as the most significant species for study, with primary concern given to the black spruce-newsprint relationship. Within this paper; wood density, compression wood, rate of growth, lignin and extractive chemicals are discussed.

Carmichael, A.J. and Ladell, J.L. 1967. Black spruce wood quality. Pp. 5-9 in Part 2: Proc. of the Tenth Mtg. of the Committee on Forest Tree Breeding in Canada. Can. Dept. For. Rural Dev., Ottawa, ON

Within the Quality Wood Unit of the Ontario Research Branch of the Department of Lands and Forests the main effort has been the development of a non-destructive sampling method to assess the specific gravity of tree boles for standing black spruce (Picea mariana (Mill.) B.S.P.) trees.

A study conducted over a two-year period - April 1964 to April 1966 - has emphasized the variations in chemical pulping and paper properties, and in wood anatomy and wood density within and between trees in black spruce.

Carmichael, A.J. and Ladell, J.L. 1966. Black spruce wood quality. Typewritten report for submission to Comm. For. J. Bot. Can., 1966. 12 pp.

Synopsis: The paper discusses the work being done on black spruce (Picea mariana (Mill.) B.S.P.) wood quality production. Within the first part of the paper the sampling assessment is discussed with an overview of the methods. The second part of the paper covers the work done by the Ontario research foundation under the main heading of inter-relation between growth rate, wood anatomy, and paper properties.

Carroll, B. 1985. Effects of precommercial thinning on 15 year old dense jack pine. H. B. Sc. For. thesis, Sch. For., Lakehead Univ., Thunder Bay, ON; 19 pp.

A study was undertaken to quantify growth increases in diameter and gross volume caused by precommercial thinning in jack pine (Pinus banksiana Lamb.). Stem analysis of mean trees showed an increase in diameter growth of 34 percent in the thinned plots in comparison to trees of similar size in the control area. This growth advantage is continuing to increase as trees in the control area become more overcrowded.

Current annual increment in gross volume per hectare is greater in the control area when all trees are taken into consideration. When only trees which will reach maturity are considered, the precommercially thinned area has greater volume increment per hectare.

Options for management of overly dense jack pine are given to aid in developing crop plans for these stands.

Cayford, J.H. 1966. Operational trials of regeneration methods for jack pine in southeastern Manitoba. OMNR, Ottawa, ON; Dept. For. Publ. No. 1165, 23 pp.

In 1960 operational trials were begun in southeastern Manitoba to test clear cutting and clear cutting in strips, pre-logging mechanical seedbed preparation, and slash scattering, seeding and planting as methods for regenerating jack pine (Pinus banksiana Lamb.) stands. Thirty-two trials were established between 1960 and 1963 on a variety of sites.

Ground preparation in conjunction with logging was unsuccessful in regenerating jack pine. However, supplementary scattering of cone-bearing slash over additional favourable seedbeds to improve upon that done during the logging resulted in an increase in stocking on most sites. Both seeding and planting resulted in successful stocking on all sites on which they were tried.

Based on results and observations from this study, and results from other jack pine regeneration studies, silvicultural recommendations are presented for the six sites in the region that commonly support jack pine stands.

Cayford, J.H. 1964. Results of a 1921 jack pine thinning in western Manitoba. Can. Dept. For., For. Res. Br., Ottawa, ON; Dept. For. Publ. No. 1077, 8 pp.

In 1921 a thinning study was begun in a jack pine (Pinus banksiana Lamb.) stand of fire origin. The purpose was "to study the effect of density on the mortality and rate of growth of naturally reproduced jack pine". Following remeasurement in 1926 the plots were re-established in 1961 providing a 40-year remeasurement period.

This study has provided another example of the response of young jack pine to intermediate cutting. Results suggest that heavy thinning will result in an increase in the production of saw timber and poles and a decrease in the production of cordwood.

Cayford, J.H. 1961. Results of a 1927 jack pine thinning in Saskatchewan. For. Res. Br., Can. Dept. For., Ottawa, ON; Tech. Note No. 107, 13 pp.

An 18-year-old jack pine (Pinus banksiana Lamb.) stand in the Boreal Forest Region in central Saskatchewan was thinned experimentally in 1927. Four plots were established where the stand averaged 4,100 trees per acre and three where it averaged 2,300 trees. Five plots were thinned to various spacings and the other two were retained for control.

The experiment has demonstrated that a single non-commercial thinning in a dense young pine stand can increase merchantable yield; board-foot-increments on thinned plots were two to three times greater than on control plots.

Cayford, J.H. and Bickerstaff, A. 1968. Man-made forests in Canada. Dept. Fish. For., Can. For. Serv., Ottawa, ON; For. Br. Publ. No. 1240, 64 pp.

Synopsis: This report is in three parts. The first part is a statistical review of man-made forests established up to 1965, with separate tabulations for afforestation, reforestation and artificial regeneration. The second part presents short synopsis of establishment and management techniques. The third part contains brief statements on performances, history, extent of forestation, silvics and damaging agents for species most commonly used to create man-made forests. A bibliography, primarily of Canadian references, is included for each species. No growth and yield data is presented.

Chang, C.I. and Kennedy, R.W. 1967. Influence of specific gravity and growth rate on dry wood production in plantation-grown white spruce. For. Chron. 43(2): 165-173.

Two hundred and thirty-two white spruce (Picea glauca (Moench) Voss) trees were sampled from 29 plots in 6 localities in southern Ontario. Specific gravities of discs cut at four-foot intervals were determined for each tree. The amount of dry wood substance contained in each tree was obtained by multiplying weighted, whole tree specific gravity by tree volume.

Although specific gravity was negatively correlated with growth rate, this reduction in dry weight per unit volume was minor in relation to the increased volumes associated with rapid growth rates. The equation using the regression of the logarithm of dry wood production on tree age was determined. Trees having dry wood production of more than 1.5 times the standard error of estimate indicated by the regression lines were selected as superior trees. The characteristics of these superior trees together with the environments in which they grew were examined. The absence of any relationship with environmental factors suggested a genetic cause of above average wood production. Superiority of a tree was mainly due to fast radial growth rate. The prospect of designing a tree breeding program to improve rate of dry wood production is discussed.

Chrosciewicz, Z. 1971. The growth response of young jack pine to moderate and extreme stand densities. Bi-M. Res. Notes. 27(1): 6.

Jack pine (Pinus banksiana Lamb.) reproduces itself readily after fire and this often results in dense sapling stands. Natural thinning is very slow and growth may be seriously hindered by overcrowding. However, neither extremes in stand density nor growth response of young jack pine to such extremes are adequately described in the literature. This note presents relevant information from two 10-year old stands in central Ontario. The results of this study provide additional evidence that jack pine density must be regulated if fast growth and desirable stand development are to be sustained.

Chrosciewicz, Z. 1963. The effects of site on jack pine growth in northern Ontario. For. Res. Br., Can. Dept. For., Richmond Hill, ON; Publ. 1015, 28 pp. (Updated in 1963, Dept. For. Publ. No. 1015).

Effects of soil moisture regime, soil texture, soil petrography, and regional macroclimate on height growth and diameter growth of dominant jack pine (Pinus banksiana Lamb.) trees were studied on various sites in Northern Ontario. Sampling was confined to pure or almost pure, fully stocked jack pine stands growing on deep, uniformly sorted, acid, podsolized, sandy soils. Generally, the height and diameter growth of dominant jack pine trees varied with the individual site factors and their combinations. With a few exceptions, the pattern of this variation was similar in both the height growth and the diameter growth.

Claughton-Wallin, H. and McVicker, F. n.d. The Jonson "Absolute Form Quotient" as an expression of taper. J. For. 346-357.

Synopsis: To express the variation in stemform, or taper, Jonson uses a new formula, the absolute form quotient. The advantage of Jonson's method is that the classification is made independent of height. Investigations were carried out in Ontario and British Columbia on the following species: Pseudotsuga menziesii (Mirb.) Franco, Picea glauca (Moench) Voss, Pinus resinosa Ait. and Pinus monticola Dougl.

Clemmer, E. n.d. On the processes regulating the growth of black spruce stands in northwestern Ontario. Univ. New Brunswick 116 pp.

A literature review of nitrogen mineralization and immobilization processes in the forest floor indicated that nitrogen availability is a critical limiting factor in the development of black spruce (Picea mariana (Mill.) B.S.P. stands. Based upon measurements of the forest floor parameters of temperature, moisture, readily energizable carbohydrate carbon and available ammonia-nitrogen, and relating these parameters to foliar nitrogen and tree volume growth on 16 black spruce stands in the Beardmore area of northwestern Ontario, a forest floor process model was developed. The model developed inferred that nitrogen availability in the forest floor and hence volume growth is dependent primarily on the mineralization potential, while the immobilization potential exerts a degree of control over ammonia-nitrogen availability in the forest floor that is inversely proportional to the mineralization potential.

Cochran, P.H. 1979. Response of thinned lodgepole pine after fertilization. Pac. Northwest For. Range Exp. Stn., USDA For. Serv., Portland, OR; Res. Note PNW-335, 6 pp.

Significant increases in volume, basal area, and bole area of lodgepole pine (Pinus contorta Dougl. ex D. Don) growth continued during the second 4-year period after application of N, P, and S. Height growth, which was not increased significantly during the first 4-year period after treatment, was increased by the initial fertilization during the second 4-year period. Grass production in the understory continues to be higher on the fertilized plots.

Cody, J.B. 1972. Some wood characteristics and properties of plantation grown red pine in New York state. Appl. For. Res. Inst., State Univ. Coll. For., Syracuse, NY; AFRI Res. Rep. No. 9, 19 pp.

This study reports on the following wood characteristics of plantation grown red pine (Pinus resinosa Ait.): specific gravity, oven-dry and green wood density, bark percent by weight and volume, and moisture content. Values are given for five Forest Districts and for all five Districts combined.

Specific gravity was found to be remarkably uniform with an overall mean of .3320. A pulping study consisting of 4 kraft cooks gave a mean overall yield of 45.1 percent and a screened yield of 44.5 percent at a kappa number of 35.8.

Cook, D.B. 1963. Spacing and layout for coniferous plantations in the northeast. J. For. 61(4): 273-277.

In the Northeast, the traditional and still widely recommended planting pattern of 6 X 6 foot squares arranged in straight lines has proved expensive. It involves both high establishment costs and high subsequent cultural expense. Trees are planted that serve no better purpose than as space fillers and as insurance against catastrophic losses. Only rarely are conscious provisions made for easy, safe and efficient extraction of forest products.

Plantations made at a spacing of 6 X 10 feet, in equidistant rows laid out with due regard for subsequent skidding requirements, not only provide adequate growing space, ample working room, and save 40 percent on the cost of establishment, but also eliminate the need for at least one noncommercial thinning - an operation hard to perform and even harder to persuade the forest landowner to perform.

Cregg, B.M.; Dougherty, P.M. and Hennessey, T.C. 1988. Growth and wood quality of young loblolly pine trees in relation to stand density and climatic factors. Can. J. For. Res. 18: 851-858.

A 10-year-old stand of loblolly pine (Pinus taeda L.) in southeastern Oklahoma was thinned to three target basal area levels: 5.8, 11.5 and 23 $m^2$/ha (control). Specific gravity, latewood percentage, date of transition from earlywood to latewood, growth, and climate variables were measured for 2 years after thinning.

The results indicate that individual tree basal-area growth can be increased by thinning without reducing wood density. From a research standpoint, the results presented here indicate the importance of accounting for climatic variation in appraising the impacts of silvicultural treatments on wood quality and growth.

Crossley, D.I. 1956. The chemical control of density in young stagnating stands of lodgepole pine. Can. Dept. North. Affairs Natl. Resour., For. Br., For. Res. Div., Ottawa, ON; Tech. Note No. 39, 17 pp.

Synopsis: This report presents the results of studies conducted to test the feasibility of using 2,4-D and ammate in the thinning of young, dense lodgepole pine (Pinus contorta Dougl.) stands. The feasibility of using a variety of formulations and dosages of both 2,4-D and ammate, applied at different seasons of the year, was also investigated. Finally the use of 2,4,5-T, both by itself, and in combinations with new formulations of 2,4-D was studied.

Crouch, G.L. 1986. Effects of thinning pole-sized lodgepole pine on understory vegetation and large herbivore activity in central Colorado. Rocky Mtn. For. Range Exp. Stn., USDA For. Serv., Fort Collins, CO; Res. Pap. RM-268, 10 pp.

The objective of this study was to document responses of understory vegetation to several levels of stocking control and to evaluate effects of the measured changes on activities of large herbivores using the thinned sites.

Thinning 65-year-old lodgepole pine (Pinus contorta Dougl.) to relatively wide spacing increased forage production, quality, and availability.

Curlin, J.W. 1968. Nutrient cycling as a factor in site productivity and forest fertilization. Pp. 313-325 in Yaugberg, C.T. and Davey, C.B., eds. Tree Growth and Forest Soils Proceedings. 3rd North American Forest Soils Conference. Oregon State Univ. Press, Oregon; 527 pp.

Synopsis: Results of several long-term fertilization experiments have shown contrasting patterns in slope, shape, and the period of the growth response function. For this paper, the literature is reviewed selectively with the intent of comparing the behaviour and movement of the macro-nutrients N,P,K and Ca from trees through the biotic phase of the nutrient cycle. For simplicity, the nutrient cycle has been discussed only in terms of single tree values and relative transfer rates within the biotic phase.

Dahms, W.G. 1973. Tree growth and water use response to thinning in a 47-year-old lodgepole pine stand. Pac. Northwest For. Range Exp. Stn., USDA For. Serv., Portland, OR; Res. Note PNW-194, 14 pp.

Results from a 5-year lodgepole pine (Pinus contorta Dougl.) levels-of-growing-stock study showed trees grew more rapidly in diameter but less rapidly in height after a first thinning at age 47. During this period, there was no substantial transfer of growth from the cut trees to the better remaining individuals. Soil moisture withdrawal was substantially reduced at lower stand densities. This unused soil moisture is potentially available for increased streamflow. Some of the site potential released by thinning may also show up as understory forage.

Dahms, W.G. 1971. Growth and soil moisture in thinned lodgepole pine. Pac. Northwest For. Range Exp. Stn., USDA For. Serv., Portland, OR; Res. Pap. PNW-127, 32 pp.

A lodgepole pine (Pinus contorta Dougl.) levels-of-growing-stock study showed that trees growing at lower stand densities had longer crowns and grew more rapidly in diameter but did not grow significantly faster in height. Gross cubic-volume increment decreased with decreasing stand density. The decrease was small per unit of density at the higher densities but much greater at the lower densities. However, at the lower densities more wood is being added to the larger trees that can reach usable size.

Soil moisture withdrawal was reduced at the lower stand densities. Understory vegetation did not develop strongly even at the low stand densities. This fact may have been partly responsible for the sharply increased diameter growth rate and reduced evapotranspiration drain on stored soil water at low densities.

Davis, K. 1935. A method of determining spacing in thinning. J. For. 33: 80-81.

Synopsis: A quick and practical method of determining proper spacing was needed as a marking guide for thinning work. A spacing diagram was prepared, showing values for diameter, basal area per tree, and number of trees per acre which correspond to values for both equilateral and square spacing. Results show that spacings per inch of DBH for 90-110, 110-140, and 140-160 square feet of basal area per acre are 1-2/3, 1-1/2, and 1-1/3 feet respectively. These constants will allow field workers to mark a stand for thinning to any given density of stocking very consistently, with a little practice.

Day, M.W. and Rudolph, V.J. 1974. Thinning planted white spruce: 5-year results. Agric. Exp. Stn., Michigan State Univ., East Lansing, MI; Res. Rep., 6 pp.

A thinning study established in a 30-year-old white spruce (Picea glauca (Moench) Voss) plantation in the Hiawatha National Forest provided an opportunity to appraise the early development of this species in plantation form and its response to several different thinning treatments. At 30 years of age, stumpage value exceeded all costs and several thinning treatments liquidated all accumulated costs for the plantation.

Growth following thinning has been good, with the treatments using an every-other row-cutting method showing the greatest growth rate. A maximum annual growth rate of 14.4% in merchantable cubic feet was attained by one treatment. At 35 years, computations show that the rate of interest earned by the stands given the various thinning treatments ranges from 6.8 to 7.4%.

Day, M.W. and Rudolph, V.J. 1970. Development of a white spruce plantation. Agric. Exp. Stn., Mich. State Univ., East Lansing, MI; Farm Sci. Res. Rep. 111, 4 pp.

Synopsis: A thinning study in a 30-year-old white spruce (Picea glauca (Moench) Voss) plantation was established to evaluate the development of this species in plantations. Row thinning was implemented.

Dillon, M.J. and Ladell, J.L. 1966. A pilot study of the relations between wood structure and the quality of paper in black spruce. Ont. Res. Foundation, Dept. Organic Chem., Ont. Dept. Lands For., Toronto, ON; Fibres Res. Rep. ORF 66-1, 53 pp. (Ont. Dept. Lands For. Wood Quality Proj.).

The results of strength on paper made from three samples of black spruce wood, previously reported, were brought together, re-analyzed, and discussed in the light of anatomical characteristics. The three samples consisted of: the corewood of a forest grown tree, the outerwood from this same tree, and a young tree grown in plantation at an accelerated rate.

This report covers the results of studies on the anatomical characteristics in relation to paper properties in three samples of black spruce (Picea mariana (Mill.) B.S.P.).

The objectives of this investigation were three in number: 1) To add to our knowledge of the patterns of variation of certain wood properties in black spruce by comparing the character of the corewood in the standard tree with that of the outerwood. As will be seen, our knowledge of these patterns in this species is meagre; 2) To attempt to assess the effect of a highly accelerated growth rate on the structure of the wood by comparing the character of the wood from the fast grown tree with that of the corewood from the standard tree, and; 3) To attempt to interpret the results of paper strength tests in the light of such differences as were found in the wood.

Dosen, R.C.; Stoeckeler, J.H. and Klip, F.G. 1957. Mechanized thinning in jack pine saplings. J. For. 55: 201-204.

As forestry in the Lake States becomes more intensive, forest managers will give more and more attention to precommercial thinning of young stands to concentrate the growth on fewer trees, and to obtain more uniform spacing. In the past, hand methods of thinning with machetes, brush knives, axes and similar hand-tools have required as many as 17 to 22 man-hours per acre. Such thinning operations have become prohibitively expensive, and some means must be sought to slash costs.

In a joint attack on this problem in 1948, the Nekoosa-Edwards Paper Company and the Lake States Forest Experiment Station started a series of experiments involving several aspects of thinning and its mechanization. Results of the study showed a 50 to 60% reduction in costs compared with hand thinning done with axes, brush knives, or machetes. The prospects of increased yields through proper utilization of growing space, and the shortening of the rotation period, plus the elimination of freight costs from distant areas make the noncommercial thinning of young jack pine (Pinus banksiana Lamb.) stands in areas near mills an attractive possibility.

Drinkwater, M.H. 1957. Field spruce in Nova Scotia. Can. Dept. North. Affairs Natl. Resour., For. Br., For. Res. Div., Ottawa, ON.; Tech. Note No. 65, 23 pp.

This report summarizes the findings of a reconnaissance in 1954 of field white spruce (Picea glauca (Moench) Voss) in Nova Scotia. The characteristics of the stands are described and recommendations made for their management. The spread of white spruce upon the abandoned farm lands in Nova Scotia has been rapid since about 1890.

Dunfield, J.D. 1975. Mechanized thinning. Pp. 123-129 in Mechanization of Silviculture in Northern Ontario Symposium.

This paper presents an overview of mechanized thinning in Canada. Most of the experimental and ongoing work has been undertaken in the Atlantic and Pacific regions, where it has been given a fairly high silvicultural priority. Several prototype and production machines have been undergoing trials in Canada.

Dunfield, J.D. 1974. Mechanized pre-commercial thinning of dense young forests. For. Manage. Inst., Dept. Environ., Can. For. Serv., Ottawa, ON; Inf. Rep. FMR-X-64, 54 pp. (Study FM-016).

The report presents an account of the historical background of mechanical, pre-commercial thinning and of the work undertaken by the Forest Management Institute in developing a prototype mechanical thinning machine. The report also describes a number of commercial brush cutters and their field tests in corridor-thinning dense, young softwood stands in eastern Canada.

Edwards, A. 1987. Cost advantages of wider plantation spacings. Silviculture Magazine. 2(4): 20-25.

Canada has vast areas of forest land and we are short of money for silviculture programs. It is essential that we re-examine our objectives and silvicultural practices to achieve them. More cost effective systems can and must be developed. The benefit/cost analysis and comparisons between different silvicultural treatments has not yet been completed. This paper examines ways to use Canada's limited silvicultural funds in a more cost effective manner.

Erdmann, G. 1988. Wood properties of plantation grown red pine in relation to spacing and radial distance from pith. H.B.Sc.For. thesis, Sch. For., Lakehead Univ., Thunder Bay, ON; 32 pp.

The effects of plantation spacing on radial variation of ring width, specific gravity and tracheid length of 36-year old Pinus resinosa Ait. were determined. Four wood samples were taken from each of three spacing trials. Ring width was determined for every annual ring; specific gravity and tracheid length were determined for every second annual ring. Major conclusions are: Varying initial spacing did not significantly affect specific gravity or tracheid length, but it did affect ring width. Radially from pith to bark, ring width decreased, tracheid length increased, and specific gravity decreased to a point and then increased.

Eversole, K.R. 1955. Spacing tests in a Douglas-fir plantation. For. Sci. 1(1): 14-18.

What is the best spacing for Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) in plantations? How does spacing affect stand development and the growth, form, and quality of individual trees? These important questions have been the subject of study since 1925 at the Wind River Experimental Forest near Carson, Washington. Here, plantations were established to test spacings ranging from 4 X 4 feet up to 12 X 12 feet. Results from these various spacing tests are discussed in this report.

Evert, F. 1983. An equation for estimating total volume of both stands and single trees of black spruce. For. Chron. 59: 26-29.

A stand volume equation is presented for black spruce (Picea mariana (Mill.) B.S.P.), based on a sample of 785 felled trees. To ensure that the equation will provide accurate estimates of the volume of both variously stocked stands and of individual trees, stand volume was expressed as the sum of individual tree volumes without direct reference to the size of the area that the trees occupy. The equation will reduce the problem of forecasting stand volume to the simpler problem of forecasting separately the individual components in the stand-volume equation.

Evert, F. and Lowry, G.L. 1970. Forest soil-site studies. III. Volume estimation and growth prediction of black spruce through stand-volume relationships. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Rep. WR-26, 31 pp.

This report is based on observations from 124 black spruce (Picea mariana (Mill.) B.S.P.) stands located in the Boreal Forest of Canada from Newfoundland to Western Ontario and from 70 selected permanent sample plots located in the northern clay belt of Ontario. It was found that mean form-height, FhL, (which is equal to the ratio of volume V, to the basal area of the same trees, G) could be predicted more accurately by using the average height weighted by basal area (Lorey's height) than by other conventional heights. Form-height equations can be written for either stand or individual tree volume prediction. Estimates of both height growth and basal area growth are presented.

Using stand volume equations and estimates of height and basal area growth, it has been possible to construct tables showing stand volume and 10-year gross volume increment for a variety of site index, basal area and age conditions. From these tables the following conclusions may be drawn for stands aged 20 years and older: 1) For a given basal area and age, gross volume growth increases with an increase in site quality. The better quality sites may be expected to produce two to four times more growth than poor sites. 2) For a given basal area and a given site index, gross volume growth decreases as the stand age increases. In order to maintain high growth rates, rotation age should not exceed fifty to sixty years except on the poorest sites. 3) For a given age and a given site index, gross volume growth increases with an increase in basal area, without indication of levelling off even at the highest basal areas observed. For maximum yields, management effort should be concentrated on the best sites and the aim should be to achieve high basal area stocking at an early age.

Farrar, J.L. 1961. Longitudinal variations in the thickness of the annual ring. For. Chron. 37(4): 323, 330, 349.

Within the crown of a tree, ring width increases from the apex to the heaviest part of the crown. Below the crown, ring width may increase or decrease. Usually it decreases; The effect is more pronounced as crowns become smaller. On vigorous trees with large crowns, ring width may increase below the crown. Trees which have been recently exposed to more light (e.g. after a stand has been thinned) often show an increasing ring width below the crown. At the base of the tree, ring width increases. Cambial growth depends on a supply of both food and growth substances.

Fayle, D.C.F. 1975. Distribution of radial growth during the development of red pine root systems. Can. J. For. Res. 5: 608-625.

The patterns of ring width throughout the root systems and stems of several 32- to 36-year-old, plantation-grown red pine (Pinus resinosa Ait.) were analyzed. All root systems showed a basic similarity in their radial sequences of ring width. Within a root system, individual sequences ranged from those similar to the radial sequence at the stem base to ones apparently dissimilar.

At the stem-root base, the increasing distance to the tree crown with time and changes in mechanical stresses with increasing tree size appeared to play major roles in the development of the basic pattern. The position and type of root, the environment of its apices, and changes in the transportation pathways in the xylem and phloem at branching points may all have influenced the pattern in individual roots.

The pattern of deposition of xylem at branching points was visualized as an interaction between the stream of growth regulators and assimilates towards the root tips and the stream of xylem water (and (or) dissolved substances) towards the root base. Discontinuities in the growth layers did not occur in the stem but increased with time in the roots, particularly in the surface horizontal roots.

Moisture availability modified the radial sequence patterns and probably influenced the shifts in longitudinal distribution of radial increment from year to year within and between the stem and the root system. The maximum current annual increment in root wood volume occurred before that in the stem.

Fielding, J.M. 1967. Wood properties in relation to growing space and thinning. in Int. Rev. For. Res. 95-126 pp.

Synopsis: This chapter consists of a literature review of wood properties with respect to growing space and thinning. Growing space influences ring width and diameter growth which in turn affects economic value. Wider spaced trees do not tend to self-prune as readily as closer spaced trees and thus tend to be knottier, reducing the wood grade. Thinning has a marked effect on wood quality.

Fleming, M.A. 1986. The analysis of a pre-commercial thinning in a 22 year-old jack pine stand. H.B.Sc.For. thesis, Sch. For., Lakehead Univ., Thunder Bay, ON; 31 pp.

A study was undertaken to quantify growth increases in diameter and gross volume resulting from a pre-commercial thinning, 12 years previously in a jack pine (Pinus banksiana Lamb.) stand. Plot data indicated a 12 percent higher average diameter for thinned plots compared to control plots. Gross volume was 39 percent greater for trees larger than 5 cm D.B.Hob. in the thinned area compared to trees in the control area.

When only trees which will reach maturity are considered the thinned area has greater volume increment per hectare.

Presently, volume increment is being lost due to inter-tree competition. A reduction in stocking from 4640 to 1948 stems per hectare is required to achieve the optimum spacing.

Foster, E. 1935. Stand-basal area curves in American yield tables. J. For. 33(1): 57-60.

It is observed that the relationship of stand-basal-area to average-stand-diameter in American yield tables are widely variable. As a result of this the question is raised whether or not the yield table procedure should be changed to make these relationships in the finished table less variable and more true to nature.

Foster, N.W. and Gessel, S.P. 1972. The natural addition of nitrogen, potassium and calcium to a Pinus banksiana Lamb. forest floor. Can. J. For. Res. 2: 448-455.

Nitrogen (N), potassium (K) and calcium (Ca) in litter-fall, throughfall and stemflow were measured over a 24-week summer-autumn period in a 30-year-old Pinus banksiana Lamb. stand. Litter-fall from the forest canopy was the major contributor of N; whereas throughfall contributed the most K to the forest floor during the study period. Stemflow accounted for a very small proportion of the nutrients received by the forest floor.

Additions of K and Ca from throughfall were greater than those from litter-fall in July and August, a period of low organic additions to the forest floor. Tree litter-fall increased in the autumn. Nitrogen concentration of this litter-fall decreased from a high of 0.92% in early summer to a low of 0.21% in autumn; whereas Ca concentration increased from a July low of 0.16% to an autumn high of 0.57%.

During September-November, overstory and understory vegetation contributed the greatest quantities of N; the overstory gave the most Ca, and the overstory, understory, and throughfall all added large amounts of K to the forest floor.

Foster, N.W. and Morrison, I.K. 1983. Soil fertility, fertilization and growth of Canadian forests. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Inf. Rep. O-X-353, 21 pp.

Fertilizer test plots have provided the best evidence for assessing soil nutrient-supplying ability in relation to tree demand. Results from experiments in adult forests across Canada and the adjacent United States support the hypothesis that lack of N generally limits growth of some coniferous species, especially on drier sites. Responses to P and K are reported only occasionally; e.g., red pine (Pinus resinosa Ait.) on outwash sands abandoned from agriculture, produced 25 to 80 $m^3$/ha of extra wood over 5 to 10 years after fertilization with K. With many species additional growth is realized when P and/or K are added with N, but generally response is not significantly greater than with N alone.

The addition of urea (224 kg N/ha) to natural stands produced, on average, an additional 15.6 $m^3$/ha of wood over 4 years with douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and 8.5 $m^3$/ha over 5 years with jack pine (Pinus banksiana Lamb.). In douglas-fir and jack pine forests, inverse relationships between site index and response to N have been found, the greatest growth increase being on poorer sites. Average 5-year responses were less with balsam fir (Abies balsamea (L.) Mill.), red spruce (Picea rubens Sarg.), white spruce (Picea glauca (Moench) Voss), and black spruce (Picea mariana (Mill.) B.S.P.).The use of foliar diagnosis and soil chemical analyses to determine which forests respond to fertilization is discussed.

Fowler, D.P. 1986. Past, present, and future of Canadian tree improvement programs. B.C. Lumberman. Jan.: 27-28.

Synopsis: Over several decades, we have accumulated a good deal of genetic information about our important tree species and this information has been used to design and implement effective applied tree improvement programs. This paper discusses the following four organizations involved in tree improvement activities in Canada: federal government, provincial governments, universities, and private organizations. The advantages of clonal propagation over conventional propagation techniques are also discussed.

Fox, G.D. and Kruse, G.W. 1939. A yield table for well-stocked stands of black spruce in Northeastern Minnesota. J. For. 37(7): 565-567.

Black spruce (Picea mariana (Mill.) B.S.P.), one of the most important conifers in northeastern Minnesota, is distributed widely throughout the northeastern United States and much of Canada. It is characteristically a very tolerant and slow-growing species which occupies poorly drained or swampy sites. Since it is a valuable and important species, officers of the Superior National Forest in northeastern Minnesota have believed for several years that a black spruce yield table would be of help in the preparation of management plans. A yield table and a stand table for black spruce, therefore, have been prepared.

Gagnon, J.D. 1965. Effect of magnesium and potassium fertilization on a 20-year-old red pine plantation. For. Chron. 41(3): 290-294.

The fertilizers, Mg at a rate of 100 lbs/acre and K at 200 lbs/acre, were applied around each of 15 red pine (Pinus resinosa Ait.) to promote increased growth in a 20-year-old plantation which had failed to fulfill growth expectations. Successive measurements of diameter and height showed that the fertilizers stimulated diameter significantly after the second growing season, but height only after the third growing season. Beneficial effect of fertilizer applications on diameter and height persisted, and the differences in diameter and height between treated and untreated trees at the end of the seventh growing season was equivalent to two years' current growth.

Gagnon, J.D. 1964. Relationship between site index and foliage nitrogen at two crown levels for mature black spruce. For. Chron. 40(2): 169-174. (Published as Forest Research Branch Contribution No. 560).

The concentration of nitrogen in current year lateral needles of 122 mature dominant and codominant black spruce trees (Picea mariana (Mill.) B.S.P.) growing on different site qualities has been studied. Analyses carried out on needles collected at the end of the growing season and within two feet of both the top and base of the crown indicated that samples obtained from either position on the crown can be related to site index or site quality. It seems, therefore, that the concentration of nitrogen in needles from the lower branches is as good a criterion of growth or productivity as that in the needles from the upper branches.

Gagnon, J.D.; Conway, J.M. and Swan, H.S.D. 1976. Growth response following fertilizer application in the Grand'Mère plantations. For. Chron. 52: 53-56.

A study was carried out in the Grand'Mère plantations on the 10-year growth response from a fertilization trial with various levels of nitrogen and potassium. There was a growth response to potassium at the end of the experiment, while the effect of nitrogen was less apparent. The best four treatments, K2, N2K2, N1K1 and K1 produced respectively 27.8, 26.9, 14.7 and 12.6 cubic meters per hectare (4.0, 3.8, 2.1 and 1.8 cunits per acre) of extra wood.

Gary, H.L. and Watkins, R.K. 1985. Snowpack accumulation before and after thinning a dog-hair stand of lodgepole pine. Rocky Mtn. For. Range Exp. Stn., USDA For. Serv. Res. Note RM-450, 4 pp.

Snowpack water equivalents were measured 5 years before and 3 years after thinning a 90-year-old stand of lodgepole pine (Pinus contorta Dougl. ex Loud) in southern Wyoming. Peak snowpack water equivalent was increased about 30%.

Gessel, S.P.; Turnbull, K.J. and Tremblay, F.T. 1960. How to fertilize trees and measure response. Natl. Plant Food Inst., Washington, DC; 67 pp.

Synopsis: This article attempts to present information on how to use soil treatments to increase tree growth, and how this growth should be measured and evaluated. In this way, forest managers are enabled to determine whether or not fertilizer treatments increase the profitability of their land.

Gevorkiantz, S.R. 1949. Proportion of various rough products in second-growth stands. Lake States For. Exp. Stn., USDA For. Serv., St. Paul, MN; Tech. Notes No. 308, 1 pp.

For good stumpage appraisal, one should know how the various sizes of bolts or cut products are distributed in the standing timber. The table herein gives a rough guide for most pulpwood stands (softwoods and aspen) in the Lake States, if reasonably well stocked and even aged. It assumes complete utilization to a 4-inch top (inside bark) with no allowance for defect.

Godman, R.M. and Cooley, J.H. 1970. Effect of initial spacing on jack pine growth and yield. Mich. Acad. 2(4): 107-111.

An evaluation was made 22 years after planting, of jack pine (Pinus banksiana Lamb.) stands established in Michigan in 1941 at spacings of 1½ x 1½, 3 x 3, 5 x 5, 7 x 7, and 9 x 9 ft. Results suggest that branch size at 22 years is a good indication of branch size at rotation age. Branches were not much larger on trees planted at 9 x 9 ft than on those planted at 5 x 5 or 7 x 7 ft. Accordingly, contrary to earlier conclusions spacing at 9 x 9 ft could be the most profitable, especially for pulpwood production.

Godman, R.M. and Olmstead, R.L. 1962. Snow damage is correlated with stand density in recently thinned jack pine plantations. Lake States For. Exp. Stn., USDA For. Serv., St. Paul, MN; Tech. Notes No. 625, 2 pp.

In April, 1961, a storm damaged two southwestern Michigan jack pine (Pinus banksiana Lamb.) plantations containing experimental cuttings. Only one growing season had elapsed since the plantations were thinned in a number of different treatments. The treatments are described in this paper, and the types and intensity of damage inflicted in the various treatment areas are discussed.

Goodell, B.C. 1952. Watershed-management aspects of thinned young lodgepole pine stands. J. For. 50: 374-378.

The thinning of dense young lodgepole pine (Pinus contorta Dougl.) stands is an accepted, silvicultural method of stimulating growth and shortening the rotation required for saw timber or pole production. Concerning areas such as those in the high mountains of Colorado and Wyoming where the primary value of the land lies in its high yield of quality water, the question arises as to whether these thinning operations are beneficial or harmful to water yields.

Indicative answers to these questions covering a period of 4 years following thinning operations were obtained from a study, reported herein, made on a typical area along the Continental Divide where the erosion hazard is low and the forest growth is dense. It is concluded that where climatic and forest conditions are similar to those studied, the thinning of dense pine stands should appreciably increase water yields. Accelerated erosion has not resulted from the thinning operations and it appears that the quality of stream flow world not suffer from similar thinnings where the climate and vegetation are such that the erosion hazard is low.

Gordon, A.M. and Morrow, L.D. 1979. Growth of young plantation black spruce (Picea mariana (Mill.) B.S.P.) in the Lake Nipigon - Beardmore area. OMNR, Nipigon, ON; 15 pp.

This study is an attempt to document the growth of upland black spruce (Picea mariana (Mill.) B.S.P.) plantations in the Lake Nipigon area which may be of interest to forest managers in plantation work in the northern part of Ontario. These plantations are well on their way to providing an acceptable yield of coniferous fibre on shorter rotation - a true black spruce forest.

Gosz, J.R. 1984. Biological factors influencing nutrient supply in forest soils. Pp. 119-146 in Bowen, G.D. and Nawbiar, E.K.S., eds. Nutrition of Plantation Forests. Acad. Press, London, EN: 519 pp. (chapter 5).

The influence of biological factors on nutrient supply is complex and there are many ways of organizing a discussion of them. I have chosen to categorize the factors by various structural and functional properties on the premise that these would relate more easily to management practices. Pure stands will be discussed primarily; however, they will be contrasted with mixed stands, natural and artificial. Succession also will be addressed to emphasize further the importance of species change on nutrient availability.

The organization of material into structural and functional properties affecting nutrient availability is intended to reveal how different forests and forest conditions affect the biological processes controlling nutrient availability. Understanding these processes is the key to managing them.

Govindaraju, D.R. 1984. Path analysis of the changes in quantitative characters in jack pine. New Phytol. 97(4): 691-696.

The magnitude of changes within a system of mutually dependent phenotypic variables in Pinus banksiana Lamb. grown under two densities was studied using path analysis. The degree of relationship among morphological characters was found to be a function of density and the relative position of crown among the competing individuals. Path analysis could be used to gain an insight into the genetic, physiological and developmental aspects of self-thinning, resource allocation and phenotypic plasticity.

Gray, J.L.; Eno, C.F.; Pritchett, W.L.; Smith, W.H. and Gooding, J.W., Tech. Committee. 1974. Cooperative research in forest fertilization: Criff annual report-1974. Agric. Exp. Stn., Inst. Food Agric. Sci., Univ. Florida, Gainesville, FL; Ann. Rep., 25 pp.

This report is a summary of some of the progress made in the Cooperative Research in Forest Fertilization (CRIFF) program in 1974, where our emphasis will be in 1975, and a brief commentary on the future.

Gray, R.L. and Kyanka, G.H. 1974. Potassium fertilization effects on the static bending properties of red pine wood. For. Prod. J. 24(9): 92-96.

The effects of correcting potassium deficiency by fertilization in a red pine (Pinus resinosa Ait.) plantation on the static bending properties of the wood produced were investigated. The data indicated that bending specimens from fertilized trees, when compared to specimens from control trees, showed significant increases in modulus of elasticity and decreases in work to proportional limit and work to maximum load, while modulus of rupture and fibre stress to proportional limit showed small changes. The overall general effect of the treatment was the production of wood which possessed strength properties comparable to those published for red pine in such sources as the USDA Wood Handbook.

Groot, A. 1982. Ten-year growth response of 45-year old Pinus banksiana Lamb. to urea fertilization and low thinning. M.Sc.For. thesis, Lakehead Univ., Thunder Bay, ON; 91 pp.

The objectives of this investigation were: 1) to examine the duration and pattern of jack pine (Pinus banksiana Lamb.) growth response to urea fertilization and low thinning, and 2) to examine methods commonly used in the measurement of fertilization and thinning trials in jack pine.

A growth model was developed to characterize the annual volume growth of individual trees. The model related the annual volume growth of an individual tree to its volume, and the stand volume. Aggregation of the annual volume increments of individual trees allowed annual stand volume increments to be estimated.

Individual trees responded to fertilization with greater 10-year volume increment and merchantable height increment. On a stand basis, fertilization resulted in about 20 cubic meters per hectare of additional gross volume growth during the ten-year response period. This volume growth response was greatest in the third and fourth years after fertilization. Fertilization appeared to have both a direct effect and an indirect effect. The direct effect was growth response to the improved nitrogen status, and this effect ceased 10 years after treatment. The indirect effect was greater growth due to larger average tree size, and this effect was still evident 10 years after treatment.

Groot, A.; Brown, K.M.; Morrison, I.K. and Barker, J.E. 1984. A 10-year tree and stand response of jack pine to urea fertilization and low thinning. Can. J. For. Res. 14: 44-50.

This study examined the 10-year effects of a light (20% basal area removed) low thinning and urea fertilization (336 kg N/ha) on a 45-year-old Pinus banksiana Lamb. stand. Thinning had no effect other than salvaging potential mortality, while fertilization resulted in an average annual gross volume growth response of about 2 cubic meters /ha/year. Volume growth response to fertilization was greatest in the largest diameter trees, and continued until 10 years after treatment. Growth response did not begin until the second growing season after treatment. There were indications that fertilization had positive effects on form factor.

Gross, H.L.; Ek, A.R. and Patton, R.F. 1980. Comparison of sample rules for estimating jack pine density, basal area, and percentage with sweetfern rust cankers. Can. J. For. Res. 10(2): 190-198.

Sample rules that rate a cluster of trees at each sample point were investigated for performance in estimating the percentage of jack pine (Pinus banksiana Lamb.) affected by cankers caused by sweetfern rust (Cronartium comptoniae Arth.). Performance for estimating the density and basal area of jack pine and cankered jack pine was also considered.

Rule performance was rated with respect to efficiency in terms of the number of clusters or trees required for an adequate sample, bias, cluster size relative to optimal cluster size, and estimate precision. The types of rules included were fixed-area strip and circular plots, point samples, strips that include a constant number of trees, and rules based on point to tree distances. All rules appeared to provide unbiased estimates of the percentage of jack pine trees or basal area affected by sweetfern rust cankers.

A cluster size of 18 was found to be optimal for such estimates with a confidence level of 80% and acceptable error size of E = ±0.05. Optimal cluster size for other error factors and an efficient cluster size range were also identified. Only point sample and fixed-area rules appeared to be unbiased for density and basal area estimates. The best rule for all variables of interest was fixed-area strips with size adjusted to include an average of 18 jack pine per sample point.

Gross, H.L.; Patton, R.F. and Ek, A.R. 1978. Reduced growth, cull, and mortality of jack pine associated with sweetfern rust cankers. Can. J. For. Res. 8(1): 47-53.

Analysis of a 13-stand sample from northern Ontario indicated that the sweetfern blister rust disease (Cronartium comptoniae Arth.) caused cankers that were associated with significantly reduced height, diameter, and volume growth of jack pine (Pinus banksiana Lamb.). Cankered trees were smaller than unaffected jack pine by an average of 20% (range 0-40%) cubic volume and 29% (range 3-53%) board volume.

Guilkey, P.C. and Westing, A.H. 1956. Effects of initial spacing on the development of young jack pine in Northern lower Michigan. Pap. Mich. Acad. Sci. Arts Lett. 91: 45-50.

A study of jack pine (Pinus banksiana Lamb.) spacing, begun in 1941 on the Manistee National Forest in lower Michigan, demonstrates the effects of stand density on the early growth of jack pine. In 1954, at fifteen years from seed, diameter growth of the dominant trees had been seriously impaired in plantations spaced 1½ X 1½ feet and 3 X 3 feet. Height growth of the dominant trees had not been affected by stand density. Plantations spaced 5 X 5 feet are developing satisfactorily now, but will need thinning before a commercial thinning is practicable. Thinnings in plantations spaced 7 X 7 feet can be deferred until a commercial thinning is possible. Plantations spaced 9 X 9 feet are too sparsely planted for satisfactory development of the stand.

Hagglund, B. 1981. Evaluation of forest site productivity. For. Abstracts. 42(11): 515-527. (Review Article).

The aim of this article is to give a review of recent research work on evaluation of forest site productivity. The paper is limited to methods of site evaluation which reflect natural productivity and are intended for use in forestry practice. Thus, for example methods for judging the suitability of fertilizing a certain site are not included.

The review does not completely cover all literature in the field of site evaluation. The main emphasis is on literature published later than 1973. The publications cited are examples of trends and ideas, chosen fairly subjectively and without aiming to be comprehensive. Because of translation difficulties, European and American literature is over-represented among the references, while for example Russian and Japanese literature is under-represented.

Hagglund, B. and Lundmark, J.E. 1977. Site index estimation by means of site properties: Scots pine and Norway spruce in Sweden. Stud. For. Suec. 138: 4-38.

The aim of this study is to establish functional relationships between site index (dominant height at a total age of 100 years) and site properties, which can be used for predicting site index in forestry. The functions are derived from a mathematical growth model, assuming that the effects of different growth factors interact in a multiplicative way. Data selected from the National Forest Survey and comprising more than 3,000 plots are used to estimate the parameters of the model by means of regression analysis. In total 10 functions are constructed-6 for Scots pine (Pinus sylvestris L.) and 4 for Norway spruce (Picea abies (L.) Karst.). These functions are checked by an examination of residuals and by a comparison with data not used for constructing the functions. The checks gave fairly satisfactory results, and the functions seem suitable for their purpose. However, site indices predicted have an accuracy considerably lower than when using site index curves in stands suitable for that method. Hence, the use of the functions should be restricted to situations where site index curves cannot be applied.

Hagner, S.O. 1967. Fertilization as a production factor in industrial forestry. Presented at H.R. MacMillan Lectureship. Univ. B.C., Vancouver, BC; 28 pp.

Application of commercial fertilizers to Swedish forests has passed through an expansionary stage. This lecture concerns the activity within the SCA (Swedish Cellulose Company). In the whole of Sweden the forest fertilization program has expanded in about the same way as the SCA program which annually has comprised about 60% of the total activity. It appears certain that we only stand in the beginning of an era which we might call the forest fertilization epoch. Calculations made in various contexts in Sweden indicate that 3.5 million acres per year can be profitably fertilized, corresponding to an annual application of 100,000 tons of fertilizers.

Forest fertilization has now proved to be a means to raise the growth potential of large areas at reasonable costs. The costs of utilizing the additional volume of timber produced by fertilization will be rather low since administration, transport, and other facilities already exist. It is also possible by forest fertilization to concentrate the additional timber production in areas where it is economically most advantageous.

Hale, J.D. and Fensom, K.G. 1931. The rate of growth and density of the wood of white spruce. Ottawa, ON; For. Serv. Circ. No. 30, 19 pp.

As a number of past investigations made at the Forest Products Laboratories and elsewhere have shown that variation in the width of growth-rings is related to variation in the density of wood it seemed advisable to investigate further the degree of such relation.

It was decided, therefore, to study some woods in greater detail than had been possible in previous investigations at the Laboratories and to examine material taken from various regions throughout the commercial range of the species examined in order to discover (in addition to the correlation between the rate of growth and density) whether wood from one region is lighter in weight than wood of the same species of identical rate of growth from a different region. The species for commencing such particular investigation of density and rate of growth was white spruce, Picea glauca (Moench) Voss.

Haley, D. 1966. The economics of forest fertilization. For. Chron. 42(4): 390-394.

The economics of forest fertilization are discussed and an economic criterion for determining the feasibility of fertilization programs is formally stated. It is suggested that research in this field is neglecting several important questions. More effort should be made to relate research to the basic economic decisions which have to be made by the forest manager. The timing and frequency of fertilizer applications appears to be particularly important from an economic point of view.

Hall, A.D. 1964. The relationship between rate of growth and specific gravity in black spruce. Ont. Dept. Lands For., Res. Br., Ontario, For. Sect. Rep. No. 50, 10 pp.

Specific gravity and rate of growth were measured for increment cores from 57 black spruce (Picea mariana (Mill.) B.S.P.) trees. When these data were grouped into four classes based on age and site, rate of growth and specific gravity showed a definite relationship for the young upland stand but an indefinite relationship for the older upland stand and for the lowland stands. Considerable variation in specific gravity was observed between individuals even after differences caused by differences in growth rate were considered. No positive conclusion could be drawn as to whether this variation was due to environmental or genetic influences, but the influence of environment was suggested by the generally higher specific gravity of the lowland trees.

Hall, A.D. 1963. The fibre characteristics of black spruce in relation to wood quality: A literature review. Ontario Dept. Lands For., Res. Br., Toronto, ON; For. Res. Rep. No. 49, 23 pp.

This report discusses some of the important factors which affect the quality of spruce (Picea mariana (Mill.) B.S.P.) wood. Fibre dimensions and characteristics; the occurrence of compression wood, and density variation within and between trees are discussed.

A survey of the literature was made and the author contends that sufficient research has been carried out to indicate that the observations made on species (Picea abies (L.)Karst, Picea glauca (Moench) Voss) with distinct late wood do not apply to spruce, at least to the same degree.

Hall, D.O. 1974. Conifer thinning guides in five steps. Intermt. For. Range Exp. Stn., USDA For. Serv., Ogden, UT; Res. Note INT-183, 10 pp.

Estimates for five elements, (a) the ring-per-inch growth rate potential, (b) the site index-basal area standard, (c) a size-merchantability limit forecast, (d) a proposed reentry period or cutting cycle, and (e) the minimum operable volume per acre, are used to suggest stems-per-acre and spacing standards for thinning operations. Ponderosa pine (Pinus ponderosa Laws.) data are used to illustrate the thinning guides.

Hall, J.P. 1986. Growth and development of larch in Newfoundland. Pp. 21-26 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as Gen. Tech. Rep. PNW-194. May 1986).

Larch (Larix laricina (Du Roi) K. Koch) occurs widely throughout Newfoundland's boreal forests on a wide variety of sites and becomes established naturally after most types of disturbance. It grows faster and produces wood of higher density than other native conifers on most sites. Exotic species of larch have shown in plantation trials to grow even faster than native larch and to have considerable potential as reforestation species.

Hambly, E.S.L. 1980. Growth of young black and white spruce in Northern Ontario. For. Manage. Sect., OMNR, Toronto, ON; 53 pp.

The Ontario Ministry of Natural Resources let a contract to obtain height growth data for young, "free-to-grow" black spruce (Picea mariana (Mill.) B.S.P.) and white spruce (Picea glauca (Moench) Voss) regenerated artificially and naturally (strip cut) in northern Ontario.

Graphs of total height and current annual height increment over age for all non-suppressed trees from "free-to-grow" plots are presented by soil texture, soil drainage, site region, stock type and season of planting. Visual differences in height growth are evident only when the data are grouped by soil texture (planted black spruce) and site region (planted black and white spruce).

Fitted growth curves (total height/age and current annual height growth/age) show that planted black spruce (upland site) grow at a slightly faster rate than planted white spruce (upland sites). Both planted spruces have superior growth to natural black spruce (lowland sites). Current annual height increment for planted spruce levels off at age 15 years to an average 41 cm/year for black spruce and 32 cm/year for white spruce. Natural black spruce exhibits an almost static current annual height increment regardless of age (10-15 cm/year).

Comments are made to the effect that the "free-to-grow" status of juvenile spruce stands can be achieved and maintained only with proper site preparation techniques and stand tending programs.

Hambly, S. n.d. Nelders: Nuggets or nonsense? Fast Growing For. Grp., OMNR, Brockville, ON; 26 pp. (Draft Proceedings).

A seminar was held in Brockville under the general theme "Nelders: Nuggets or Nonsense". The Nelder trial design allows a large range of spacings to be tested over a small land area. Current Nelder knowledge in Ontario, from the conifer Nelders in the north and the poplar Nelders in the southeast, gives us the opportunity to assess the effect of spacing on growth. We can work out in advance some relationships which will be useful in making management decisions as we come to situations where we have more rigorous control on where, what and how we plant seedlings. And of course, we must remember that tending is an important ingredient in obtaining reliable information from Nelder trials and in producing productive plantations.

Through the day's program, the following topics were covered: 1) what does management need to know, 2) current state of knowledge, 3) establishment, analysis and interpretation, 4) analytical techniques, 5) biological and physiological considerations, and 6) the application of Nelder spacing trial information to operational forestry. An abstract of each paper is presented to document the "nuggets" shared during a most enlightening day.

Hamilton, G.J. 1976. The Bowmont Norway spruce thinning experiment 1930-1974. Forestry. 49(2): 109-121.

Various effects of four different thinning treatments in Picea abies (L.) Karst., after a period of 44 years, are outlined and discussed. In particular, there was found to be no significant difference between C, D, and LC grades in total volume production. The D grade thinning is shown to be the most favourable from an economic viewpoint.
**Note: Def'n of Thinning Grades:**
B grade = defined as the removal of dead and dying trees only, but in this experiment some suppressed trees which were not in these categories were also removed in the early thinnings.
C grade = a moderate low thinning intermediate between B and D.
D grade = a heavy low thinning in which only the best trees, mainly dominants, are left and given space for full crown development.
LC grade = a 'light' crown thinning. LC grade resembles D except that suppressed and sub-dominant trees are left to fill the spaces between the best dominants. Poor Co-dominants and dominants are removed.

Hamilton, G.J. n.d. Effects of line thinning on increment. Pp. 37-45 in Hamilton, G.J. ed. Aspects of Thinning: Economics and harvesting of thinning. For. Commission, London; (Publ. as For. Commission Bull. No. 55).

Almost irrespective of the methods employed in harvesting, line thinning has a number of advantages over selective thinning, which are fairly well understood. In the first place the need for marking the trees to be removed is more or less dispensed with. Secondly, it is usually unnecessary to undertake the intensity of brushing which would be required for selective thinning and hence the costs of this operation are either reduced or eliminated. The third advantage is that line thinning facilitates tree felling operations. Fourthly, it improves general access to the crop and usually assists extraction.

In order to make a rational appraisal of any one thinning it is therefore necessary to consider both short and long term effects, whether beneficial or otherwise. This paper is confined to the consideration of the effect of the various forms of line thinning on the increment of the remaining crop.

Hannula, O. 1971. The effect of average stand diameter on tree-length logging costs. Pulp Pap. Mag. Can. 72(2): 96-100. (WS Index 2577 (B-1).

A study to determine the effect of average stand diameter on tree length logging costs was made near Hinton, Alberta, on the limits of North Western Pulp and Power Limited during 1968. The production data from 32,000 cords of spruce formed the basis of this particular study. This report deals with the data collection, statistical analysis, and deduction made from the results.

There were three main reasons for carrying out the study. First of all, it was important that logging costs for various sizes and types of stands be known in order to have the basic material for a marginal cost analysis. This type of analysis is a decision-making guide to allow maximization of profits. Secondly, the effect of variations in production rates in various stand sizes and types, on large scale logging operations, influences the preparation of cutting and hauling schedules. Finally, a study of this nature can indicate deficiencies in the logging system. For example, a three-man crew of production was not up to normal. The procedures used for the collection and analysis of data are too complicated to go into detail so only the important factors are covered in this paper.

Hansen, T.S. and Brown, R.M. 1929. Some results of thinning jack pine. J. For. 27: 275-279.

In recent years jack pine (Pinus banksiana Lamb. ) has increased tremendously in commercial importance. The value of definite information on the results of thinning jack pine stands was recognized early at the Cloquet Forest Experiment Station where this species, in less than fifteen years, has increased from an almost negative stumpage value to a present value that cannot be ignored. In 1912 - 1914, a half-acre thinning plot was established in a 37-year-old stand of jack pine, the results of which are presented in this paper.

Harding, R.B.; Grigal, D.F. and White, E.H. 1985. Site quality evaluation for white spruce plantations using discriminant analysis. Soil Sci. Soc. Am. J. 49: 229-232.

Fifty-six study plots were established in fully-stocked white spruce (Picea glauca (Moench) Voss) plantations, 33 to 43 yr old, in northern Minnesota. The plots were separated into three growth response groups based on site index, basal area, and mean annual biomass increment of the spruce.

Discriminant analysis was used on data from 50 of the plots to determine the site descriptors that best separated the plots into their respective growth groups. The discriminant functions, based on seven descriptors, correctly classified 76% of the plots. Plots in group 1, 2, and 3, roughly equivalent to good, medium, and poor productivity, were correctly classified 69%, 80%, and 79%, respectively. When individual plots were sequentially deleted from computation of the functions (jackknife analysis), these values dropped to 56%, 75%, and 71%, with an overall value of 68%. Three of the remaining six independent test cases were correctly classified.

Slope, soil phosphorus, and nutrient synecological coordinates were all major discriminators. These discriminators represent physiographic, soil, and vegetation properties, and demonstrate the importance of the total site approach when defining site quality for white spruce.

Harrington, C.A. and Reukema, D.L. 1983. Initial shock and long-term stand development following thinning in a Douglas-fir plantation. For. Sci. 29(1): 33-46.

Responses following the application of six precommercial thinning treatments to a 27-year-old Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) plantation (2.4 m spacing, height at age 100 = 24 m) have been monitored for 25 years. Spacing after thinning ranged from 3.4 to 8.1 m.

Immediately following thinning, trees exhibited thinning shock; that is, substantial height growth reductions. The severity and duration of the shock effect were partially related to the severity of thinning. From 15 to 25 years following thinning, however, height growth was positively related to growing space with the best height growth at the wider spacings. Diameter growth increased following thinning, with the range in diameter growth rates between spacings increasing over time. Basal area and volume growth per hectare were reduced by treatment, but the differences among spacings are decreasing.

Hatcher, R.J. 1964. Notes on black spruce management and research in Quebec. Pulp Pap. Mag. Can. WR 420-426.

The forest industries of Quebec have recently begun to tap the last large wood reserve in the province. Is there any reason to suspect that present day forestry practice may be detrimental to the renewal of this resource? Are there any current trends in forestry practice that may affect this forest? What is known about black spruce (Picea mariana (Mill.) B.S.P.; what is the current research program and should it be supplemented by additional studies? A brief look at these questions is the subject of this paper.

Hedin, I.B. 1982. Five case studies of precommercial thinning in British Columbia and Alberta. For. Eng. Res. Inst. Can., Vancouver, BC; Tech. Note No. TN-62, 29 pp.

Precommercial thinning (PCT) (juvenile spacing) is an important stand treatment in both natural and planted stands. It was identified by a Council of Forest Industries survey in 1978 as the highest priority treatment requiring mechanization.

For our first investigations in PCT in 1981, we undertook five case studies: three on Vancouver Island, one in the British Columbia Interior and one in Alberta. These provided first hand observations of present practices. The data from these will help foresters in planning or supervision of PCT operations and will also help in the development of new techniques to overcome the limitations of present techniques. The main species involved in the studies were: Pinus contorta Dougl., Pseudotsuga menziesii (Mirb.) Franco , Tsuga heterophylla (Raf.) Sarg. , Thuja plicata Donn ex D. Don.

Heger, L. 1971. Site-index/soil relationships for white spruce in Alberta mixedwoods. For. Manage. Inst., Can. For. Serv., Ottawa, ON; Inf. Rep. FMR-X-32, 15 pp. (Project No. 31).

Site-index curves, based on the height of dominant trees and a breast-height age of 50 years, were developed using the regression method, for white spruce (Picea glauca (Moench) Voss) on two types of parent material and in four drainage classes within the Mixedwood Forest Section of Alberta, to determine differences in curve shape and in average site index.

Heger, L. and Lowry, G.L. 1971. Applicability of Plonski's yield tables for black spruce in central and eastern Canada. For. Chron. 47(5): 282-285.

The normal yield tables currently used for black spruce (Picea mariana (Mill.) B.S.P.) in northern Ontario are based on extensive data collected in pure, or almost pure, even-aged stands located between longitude 79° and 95° W, and latitude 46° and 52°. To those stands Plonski's tables may be readily applied. The present study was made to determine whether these tables are applicable to stands located outside the above limits.

Heger, L. and Lowry, G.L. 1970. Forest soil-site studies. IV. Site-index curve shape in black spruce in eastern Canada. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Rep. WR-31, 12 pp.

A sample of 1169 stem analyses of black spruce (Picea mariana (Mill.) B.S.P.) was collected from 124 stands located in an area extending from western Ontario through Newfoundland. The sample was divided into subsamples of spruce classed according to: (A) Breast height (BH) age at the time of felling; (B) Crown class; (C) Climatic-geologic region; (D) Soil moisture regime; and (E) Vegetational site type. A set of site-index curves was derived for each subsample. Ordinates of the points defining the curves at 5-year BH age intervals were compared at each age interval. Most differences were below 2.0 feet. The largest difference, 5.6 feet, was between the curves for dry and very moist sites. It was concluded that, with exception of dry sites, a single set of curves based on pooled data from all the investigated sites may be about as precise as curve sets based on data from individual sites.

Hegyi, F. 1973. Optimum plot dimensions for experimental designs in jack pine stands. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Inf. Rep. O-X-181, 13 pp.

Three jack pine (Pinus banksiana Lamb.) stands were selected in northern Ontario to cover age classes 40-45, 45-50, and 55-60 years. In each stand a 2.0-ha square was demarcated and the rectangular coordinates, dbh, and height of each tree were measured; these measurements were then stored in the computer. The three stands were subdivided by a computer program into plots of various sizes and shapes, and mean, variance, standard deviation, and the coefficient of both skewness and kurtosis were calculated for each plot as well as for each stand. Using the coefficient of variation and, to a lesser extent, the coefficient of skewness and of kurtosis as the main criteria, plot sizes are recommended for experiments in jack pine.

Hegyi, F. 1972. Dry matter distribution in jack pine stands in northern Ontario. For. Chron. 48(4): 193-197.

The objective of this paper is twofold: to provide dry matter distribution data for jack pine (Pinus banksiana Lamb.) trees, and to define how age affects dry matter production in jack pine stands.

Hegyi, F. 1970. Growth and yield of jack pine in mixed-even-aged stands in Northern Ontario. For. Res. Lab. Ont. Region, Can. For. Serv., Sault Ste. Marie, ON; Inf. Rep. O-X-140, 36 pp.

The growth and yield of jack pine (Pinus banksiana Lamb.) in mixed-even-aged stands in northern Ontario is examined by using multiple linear regression techniques. Basal area, mean height, and volume growth are predicted on five biologically defined site types. Although it is recommended that, in general, the regression equations should be used for growth prediction, a set of variable density yield tables is also given to serve as guides for forest management.

Hills, G.A. 1960. Regional site research. For. Chron. 36: 401-423.

In Ontario, studies of land-forest relationships are conducted within the framework of site regions. Site regions are regions within which the effectivity of macroclimate is assumed to be relatively uniform since these regions are established through comparing the natural succession of vegetation on similar landforms, rather than by meteorological data. From the stand point of forestry practice, the most pertinent feature of a site region is that it is an area in which similar responses may be expected from similar natural disturbances and forestry practices within similar combinations of landforms and forest types.

The aim of regional site research is: (i) to describe the various physiographic conditions occurring in a site region so that foresters and land-use planners may recognize them, and (ii) to provide information regarding forest distribution, forest succession and the capability of these physiographic site types to produce forest and other crops, which information may aid these people in designing silvicultural experiments, in making forest management decisions, or in planning alternative uses of the land. Examples have been drawn from the site regions of Ontario to illustrate the principles and methodology of regional research.

Holmsgaard, E. 1958. Comments on some German and Swedish thinning experiments in Norway Spruce. For. Sci. 4(1): 54-60. (Abstracted from Forestry Abstracts).

Synopsis: Discusses Assmann's theory of maximum, optimum and critical basal area, Carbonnier's report on Swedish experiments, Burger's account of a Swiss experiment and Moller's experience in Denmark and argues that most of the published papers showing that stand increment is dependent on thinning grade are open to serious objection because the material is insufficiently analyzed; information on the basic material is insufficient, and experiments have not been of sufficient duration. Long-term experiments are necessary, because increases following thinnings are followed by counterbalancing decreases and this factor has received too little attention. Assmann is of the opinion that the optimal basal area varies in different localities for Norway spruce (Picea abies (L.) Karst.); optimal basal area is highest in areas where growth is good.

Horton, K.W. and Lees, J.C. 1961. Black spruce in the foothills of Alberta. For. Res. Br., Can. Dept. For., Ottawa, ON; Tech. Note No. 110, 54 pp.

In 1957, empirical studies of black spruce (Picea mariana (Mill.) B.S.P.) habitat-growth relationships and silvical characteristics were undertaken to enable comparisons with findings from other regions. The field work took the form of several specialized surveys in selected conditions. The conditions and procedures involved in each aspect are described together with the results, which are interpreted in the light of the relevant literature.

Host, J. and Schlieter, J. 1978. Low-cost harvesting systems for intensive utilization in small-stem lodgepole pine stands. Intermtn. For. Range Exp. Stn., USDA For. Serv., Ogden, UT; Res. Pap. INT-201, 20 pp.

Three different skidding methods--small rubber-tired skidder, horse, small tracked tractor--were compared in an overmature Pinus contorta Dougl. stand in Montana. Five comparable units were logged using two different utilization standards--loggers' choice and 2 ½-inch top d.i.b. Skidding production, product volume removed per acre, and residue volume per acre are compared for each cutting unit. Skidding costs, in order of increasing costs were rubber-tired skidder, horse, and then farm tractor. On a capitol investment basis, horse skidding is the most efficient.

Hunt, K. 1977. Kraft pulp yields from fertilized and thinned jack pine. Tappi 60(8): 136-137.

Synopsis: Pulp-yield and specific gravity of jack pine (Pinus banksiana Lamb.) were little affected by thinning and/or fertilizing treatments. Total biomass added by these treatments was not examined, but it must be analyzed before the economics of silvicultural manipulation of trees for pulp can be assessed.

Innes, M.R. 1967. An economic analysis of white spruce plantations in southern Ontario. M.Sc.For. thesis, Univ. Toronto, Toronto, ON; 57 pp.

The necessity of knowing the financial return to an acre of land in southern Ontario resulting from the growing of a white spruce plantation is discussed. Yield estimates were established for plantation white spruce (Picea glauca (Moench) Voss) growing on three site classes. The costs and revenues associated with growing a white spruce plantation for pulpwood production alone were combined for each site class by means of the Faustman formula to produce soil expectations values per acre. It is concluded that under the present market conditions white spruce plantations in southern Ontario should be managed on a 40 year rotation to produce only pulpwood.

Jackson, M. and Megraw, R.A. 1986. Impact of juvenile wood on pulp and paper products. Pp. 75-81 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

For many years and backed with considerable data, it has been known that in southern pines the juvenile wood gives different pulp and paper properties compared to mature wood. Linear relationships exist between wood specific gravity and several important pulp and paper properties. These include paper-tear, burst strength and paper sheet density.

In the western forests, data is much more limited but Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) juvenile wood does follow a similar pattern with respect to pulp and paper properties. This paper will discuss the results of a study comparing the behaviour of wood from various parts of Douglas-fir trees in the kraft pulping process. The paper will present the results in comparison to the southern pine data because a large body of well documented studies exist for southern pine.

Jeglum, J.K. 1983. Changes in tree species composition in naturally regenerating strip clearcuts in shallow-soil upland black spruce. Pp. 180-193 in Wein, R.W.; Riewe, R.R. and Methven, I.R. eds. Conference Proceedings - Research and Dynamics of the Boreal Zone. Assoc. Can. Univ. for North. Stud.

A long-term study of regeneration in alternate strip clearcuts in shallow-soil upland black spruce (Picea mariana (Mill.) B.S.P.) near Nipigon, Ontario, has revealed shifts in tree species composition. The original forest was dominated by black spruce and had minor tree size components of jack pine (Pinus banksiana Lamb.), balsam fir (Abies balsamea (L.) Mill.), trembling aspen (Populus tremuloides Michx.) and white birch (Betula papyrifera Marsh.). The regenerating first cut strips are a mix of black spruce-white birch-trembling aspen, and the proportion of hardwood to conifer is about 50:50. Scarification increased the level of regeneration in the upland site positions for all species except balsam fir. In lower slopes and peaty drainageways, black spruce regenerated slightly better in nonscarified strips. Regeneration of black spruce increased from 51 to 65 per cent between two and four years of natural seeding. Comparisons of these results with regeneration in clearcuts on the limits of American Can Canada Inc. indicate that strip cutting provides much more regeneration of both conifers and hardwoods. Shallow-soil sites should be classified and managed on the basis of at least two subtypes - fragile nonplantable, and plantable. The manager should make explicit plans as to how he intends to manage hardwoods in cutover upland black spruce forests.

Jeglum, J.K. 1974. Relative influence of moisture-aeration and nutrients on vegetation and black spruce growth in northern Ontario. Can. J. For. Res. 4: 114-126.

Results from a principal component analysis suggest that nutrient regime is more important to vegetational variation than the moisture-aeration regime. Correlations between site index and habitat measures suggest that the moisture-aeration regime influences tree growth more than the nutrient regime. For particular components of vegetational variation and for segments of the total data, the proportional influence of the two gradients varies. Moisture-aeration and nutrient regimes explain a large proportion of the variation in minor vegetation and tree growth on black spruce (Picea mariana (Mill.) B.S.P.) peatlands.

Jeglum, J.K.; Haavisto, V.S. and Groot, A. 1982. Peatland forestry in Ontario: An overview. Pp. 1-56 in Peat Symposium '82. 56 pp.

Physical damage to site and inadequate regeneration are two of the most severe problems in peatland forestry in Ontario. Forest management agreements between the province and major forest product companies have shifted some of the responsibility for regeneration to the companies, and have focused on the importance of integrating harvesting and regeneration activities. The importance of management according to site types and other site considerations is generally accepted, but less generally applied. In this overview, the status of peatland forestry is assessed in terms of logging methods and impacts, harvesting-regeneration systems, site preparation, tending, and species selection. Some of the current strategies for regenerating and managing peatland forests are reviewed.

Joergensen, C. 1951. Experimental thinning operations on a commercial scale. For. Chron. 27(1): 64-72.

Synopsis: This paper presents information on the technical and economic possibilities of thinning with respect to frequency, intensity and methods used, and expectation information. An experiment involving thinning of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco var. menziesii) is described.

Johnstone, W.D. 1982. Heavy thinning accelerates growth of 77 year old lodgepole pine. Can. For. Serv., Edmonton, AB; For. Manage. Note No. 16, 3 pp.

Synopsis: This report presents the response of 77 year old lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm) for 21 years after treatment. Thinning had a pronounced effect on the diameter growth of the pine trees during the 21 years following treatment and stimulated growth in older trees.

Johnstone, W.D. 1982. Juvenile spacing of 25-year-old lodgepole pine in western Alberta. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-244, 19 pp.

The effects of spacing 25-year-old fire-origin lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) in western Alberta are reported 10 years after treatment. Five spacing levels of 494, 988, 1977, 3954, and 7907 tree per hectare (200, 400, 800, 1600, and 3200 trees per acre) were established on plots located on three site types. Data were analyzed in terms of the entire stand and portions of it. Spacing had a significant effect on stand and crop-tree growth and development. Wide spacing resulted in greater diameter increments and greater stand and crop-tree average diameters.

Johnstone, W.D. 1981. Effects of spacing 7-year-old lodgepole pine in west-central Alberta. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-236, 18 pp.

The effects of spacing 7-year-old fire-origin lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) are reported 13 growing seasons after treatment. Five spacing levels of 494, 988, 1977, 3954, and 7907 trees per hectare (200, 400, 800, 1600, and 3200 trees per acre) were established on plots at three sites in west-central Alberta. Data were analyzed in terms of the entire stand and portions of it. Wide spacing had a significant effect on stand growth and development, resulting in greater diameter increment and average stand diameter. The effects on crop-tree development were inconclusive. Spacing specifications are recommended for young lodgepole pine.

Johnstone, W.D. 1981. Precommercial thinning speeds growth and development of lodgepole pine: 25-year results. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; Inf. Rep. NOR-X-237, 30 pp.

The effects of thinning 22-year-old fire-origin lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) are analyzed 25 years after treatment. Four spacings between 1.5 x 1.5 m and 3.7 x 3.7 m plus a rethinning 15 years later of an original 1.8 x 1.8 m spacing were carried out in west-central Alberta. The results are presented for individual trees, the entire stand, and 500 crop trees per hectare. Thinning improved individual tree growth, particularly diameter growth, with the greatest response occurring at the widest spacing. The thinning also resulted in larger and faster growth of average stand values. In the thinned plots all per-hectare stand values except basal area were as large as or larger than those in the unthinned plots. Percentage survival was higher on the more heavily thinned plots. All average and per-hectare crop-tree values were larger for thinned than for unthinned stands.

Johnston, W.F. 1977. Manager's handbook for black spruce in the North Central States. North Cent. For. Exp. Stn., USDA For. Serv. Gen. Tech. Rep. NC-34, 18 pp. (This handbook supersedes Johnston, W.F. 1971. Management Guide for the Black Spruce Type in the Lake States. USDA For. Serv. Res. Pap. NC-64).

Synopsis: Summarizes timber management considerations for black spruce (Picea mariana (Mill.) B.S.P.) on: 1) controlling growth; 2) controlling establishment and composition; 3) controlling damaging agents; and 4) other resource considerations. A key to recommended management practices is given for pulpwood and Christmas tree growing, and requirements for successful broadcast burning are included.

Kabzems, A. and Kirby, C.L. 1956. The growth and yield of jack pine. Sask. Dept. Nat. Resour., For. Br., Saskatchewan; Tech. Bull. No. 2, 66 pp.

Synopsis: This report provides some basic data on growth and yield of jack pine (Pinus banksiana Lamb.) in Saskatchewan. Observations and measurements on thinning, seeding, planting and other silvicultural experiments demonstrated in this province are also discussed.

Kamp, B.J. van der and Spence, M. 1987. Stem diseases of lodgepole pine in the British Columbia interior following juvenile spacing. For. Chron. 63: 334-339.

The incidence of western gall rust (Endocronartium harknessii (J.P. Moore) Y. Hiratsuta), stalactiform blister rust (Cronartium coleosporiodes Arth.) and comandra blister rust (C. comandrae Pk.), and atropellis canker (Atropellis piniphila (Weir) Lohm and Cash) was measured in four sets of permanent sample plots in young lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) stands in the interior of British Columbia in 1980 shortly following operational juvenile spacing and again in 1985. The incidence of these diseases in 1980 was often higher in the spaced areas than in unspaced controls indicating that diseased trees were not preferentially removed. The 1985 remeasurement showed that new gall rust and comandra rust infections occurred with equal frequency in spaced and control areas while the increase in the incidence of stalactiform rust was much greater in thinned than in unthinned control areas. The pattern for atropellis canker was not clear. The proportion of trees with one or more infections by these diseases in 1980, and the number of infections per diseased tree, increased significantly with diameter in both thinned and control areas. By 1985 only 60.8 percent of the original number of trees in the thinned areas and 74.8 percent in unthinned control areas remained free of stem infections or threatening branch infections by these diseases.

Kelertas, R.D. 1977. Growth response of immature jack pine (Pinus banksiana Lamb.) to nitrogen (urea) fertilization -- fifth-year results. Typewritten report prepared for the OMNR, Div. For. 27 pp.

Two jack pine (Pinus banksiana Lamb.) stands (20 and 30 years of age) were fertilized aerially with urea and growth responses were measured using specific volume and current annual height increments (CAHI) along with the conventional measures of basal area and total volume increase. Specific volume and CAHI were the parameters that showed a significant increase in the 20-year-old stand but displayed less increase than a 50-year-old stand measured similarly in a past study. The 30-year-old stand showed no significant response to fertilizer applications. Stand density and the level of fertilizer treatment may have implications. Plantations of younger ages (10 years old) are cited as good sites for better growth responses to fertilization.

Ker, M.F. 1976. Metric yield tables for the major forest cover types of Newfoundland. Newfoundland For. Res. Cent., Can. For. Serv., St. John's, NF; Inf. Rep. N-X-141, 79 pp.

Synopsis: This report provides a set of metric yield tables based on those published earlier in the English system. This metric version incorporates only a change of units plus a taper factor. Metric yield tables are given for the following cover types: balsam fir (Abies balsamea (L.) Mill.), black spruce (Picea mariana (Mill.) B.S.P.), softwood/hardwood, hardwood/softwood, white birch (Betula papyrifera Marsh.), and trembling aspen (Populus tremuloides Michx.).

Khanna, P.H. and Ulrich, B. 1984. Soil characteristics influencing nutrient supply in forest soils. Pp. 79-117 in Bowen, G.D. and Nambiar, E.K.S. eds. Nutrition of Plantation Forests. Acad. Press, London; 519 pp. (Chapter 4).

This chapter deals with the chemical characteristics of forest soils, with emphasis on those under plantations, with the intention of providing a basis for understanding the nutrient-supplying capacity of soils in relation to nutrient demands by plantation trees. Changes in soil chemical characteristics as a consequence of management practices, including the introduction of exotic tree species in plantations, are considered in relation to buffering systems operating in different soils. A theory on the stability of forest ecosystems based on nutrient dynamics is presented. Based on these theoretical considerations, silvicultural practices for a sound management of plantations are discussed.

Klem, G.S. 1968. Quality of wood from fertilized forests. Tappi 51(11): 99A-103A.

The main effects on wood characteristics of fertilization of spruce and pine forests are an increase in the number of cells produced and a slight change in the springwood-to-summerwood ratio. Changes in size and shape of the cells are smaller and less consistent. The specific gravity of the wood after fertilization will depend on the growth of the tree before treatment. In most forests, fertilization will reduce the specific gravity approximately 5%. This reduction, however will be more than compensated for by the increase in volume production. The total production of cellulose per acre may likewise be assumed to increase with fertilization. The greater amount of springwood tracheids in the pulp will influence the paper qualities in the direction of lower tear resistance and higher burst and tensile strengths. The reduced variation in wood characteristics, together with a reduction in the amount of heartwood, will facilitate pulp production and increase the homogeneity of the pulp, while the amount of fines and debris will be reduced. Fertilization has under certain conditions been reported to reduce tracheid length and wall thickness significantly but the changes under normal growth conditions are considered to be too small to noticeably influence paper qualities.

Knowles, R. 1964. A preliminary study of the metabolism of ammonium and urea by black spruce raw humus. Pulp Pap. Res. Inst. Can., Montreal, QU; Tech. Rep. Ser. No. 371, Woodl. Res. Index No. 155, 15 pp.

The Woodlands Research Department is conducting a field experiment at Baie Comeau in a black spruce (Picea mariana (Mill.) B.S.P.) stand with a large accumulation of raw humus, and the various effects of thinning with and without urea fertilization are being studied. The present work is concerned with nitrogen transformations in the raw humus as they may affect the availability of nitrogen for tree nutrition. By means of the soil percolation technique, gross changes in microbial populations were studied as well as transformations of ammonium and urea added to humus from both untreated and urea-treated plots.

The results indicated that following field or laboratory application of urea the following marked changes occurred in the raw humus: an increase in pH of as much as two units; a decrease in organic matter content over a long period in the field; a great increase in numbers of bacteria; and an increase in the amount of water-leachable ammonium present in the humus.

Following the addition of ammonium as such, there was evidence of a rapid fixation or immobilisation of the ammonium-nitrogen. The loss of nitrogen as volatile ammonia appeared to be dependent upon pH which itself was related to the concentration of the non-fixed or water-leachable ammonium. Under the experimental conditions, appreciable loss occurred only above pH 7.0.

From the point of view of tree nutrition, the results suggest that, whereas untreated raw humus may be very deficient in mineral forms of nitrogen, the addition of urea leads to the production of sufficient mineral nitrogen to ensure that nitrogen is no longer the limiting factor for growth.

Kozlowski, T.T. and Peterson, T.A. 1962. Seasonal growth of dominant, intermediate, and suppressed red pine trees. Bot. Gaz. 124: 146-154.

The present study, conducted in a 34-year-old managed red pine (Pinus resinosa Ait.) plantation, was initiated to further characterize the nature of intraspecific competition by determining seasonal growth characteristics of plantation-grown coniferous trees of varying crown classification and degree of suppression.

Krabbe, P. 1984. A black spruce growth and yield model at three planting densities. OMNR, Thunder Bay, ON; 13 pp.

A model utilizing growth data from sources mainly concerning white spruce (Picea glauca (Moench) Voss) plantations was used to estimate rotation ages for an unthinned black spruce (Picea mariana (Mill.) B.S.P.) plantation at varying densities.

Results of the study show: 1) close spacing will utilize the site production capacity sooner than would wide spacing, 2) early gains in volume production with close spacing is lost to mortality due to competition, 3) the rotation age of black spruce is estimated to be between 60 and 67 years, 4) 8 ft. by 8 ft. spacing appears to be better than 6 ft. by 6 ft. spacing if there is 100% survival, 5) there is little information available on the growth and yield of black spruce plantations past the age of 25, and 6) more models are required to reflect the field planting conditions.

Krahmer, R.L. 1986. Fundamental anatomy of juvenile and mature wood. Pp. 12-16 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

Stems of coniferous trees contain zones of both juvenile and mature wood, and these zones have significantly different properties. The nature of a zone and its location in a wood product affect the performance of the product. This paper presents a description of tree anatomy, wood qualities, and the terms used in characterizing juvenile and mature wood and in studying their properties.

Krause, H.H. 1970. Factorial experiments with nitrogen, phosphorus and potassium in spruce and balsam fir stands. III. Early growth response. Univ. New Brunswick, Fredericton, NK; 20 pp.

Basal-area increments of fertilized and untreated trees in maturing stands of black spruce (Picea mariana (Mill.) B.S.P.), mixed red spruce (Picea rubens Sarg.) and balsam fir (Abies balsamea (L.) Mill.), and pure balsam fir were calculated from annual measurements with permanently installed dendrometer tapes.

Black spruce responded to N and P additions. Combined N and P treatment produced annual growth increases of 104% and 72%. Red spruce responded significantly to N treatment. Addition of this element approximately doubled growth during mid- and late-season of the second year following treatment. Balsam fir in mixture with red spruce showed a significant response to N addition and exhibited further growth increase due to N x P and N x K interactions.

Growth of a pure balsam fir stand could not be improved by separate applications of either N, P or K. But notable although statistically not significant growth increases resulted from P x K and N x K interactions.

Growth response of black spruce was positively correlated with fertilizer-induced increases in foliar N content, and negatively correlated with increases in foliar K. Plotting foliar P contents against basal-area increments indicated luxurious consumption of this element when furnished without simultaneous N additions. On N-treated plots growth tended to increase with increasing P/N ratio.

Krause, H.H.; Weetman, G.F. and Koller, E. 1977. Nitrogen improves growth for balsam fir, jack pine and black spruce-jack pine stands. Pulp Pap. Mag. Can. 78(6): 65-68.

Synopsis: The Interprovincial Forest Fertilization Program covers 78 methodical experiments carried out in the following provinces: Nova Scotia, New Brunswick, Quebec, Ontario, Saskatchewan, Manitoba and Alberta. The aim of the program was to determine the effects of using fertilizer on the growth of conifer plants, in the semi-mature state, before harvest.

Observations carried out in 30 nursery hotbeds, at 5 year intervals, showed that using large scale application of fertilizers stimulated plant growth of black spruce (Picea mariana (Mill.) B.S.P.) and jack pine (Pinus banksiana Lamb.) in Saskatchewan, and growth of Pinus banksiana Lamb. in Manitoba, Ontario and Quebec.

In the case of balsam fir (Abies balsamea (L.) Mill.) in Gaspé and Cape Breton Island, the use of fertilizers amounted to nothing extraordinary, because of moderating effects.

Ladell, J.L. 1971. Variation outward and some internal correlations in the wood of black spruce, Picea mariana (Mill.) B.S.P. Ont. Res. Foundation, Sheridan Park, ON; 54 pp. (Occasional publication).

Synopsis: The objective of this work was to prepare a short list of criteria by which the pulp and paper making qualities of individual trees could be predicted from wood characteristics. An overview of the structure of black spruce (Picea mariana (Mill.) B.S.P.) wood is presented.

Ladell, J.L.; Carmichael, A.J. and Thomas, G.H.S. 1968. Current work in Ontario on compression wood in black spruce in relation to pulp yield and quality. Pp. 52-60 in Wright, J.W., chairman. Proc. 8th Lake States For. Tree Improv. Conference. North. Cent. For. Exp. Stn., USDA For. Serv.; 60 pp.

A point sampling system was used to measure the amount of compression wood in over 400 discs from 11 mature black spruce (Picea mariana (Mill.) B.S.P.) trees grown on a good lowland site in Challies Township, Ontario. Overall mean compression wood content in the 11 trees was found to be 13.9 percent by volume, with mean values in individual trees varying from 5.3 to 26.1 percent. Compression wood content tended to be higher at the base and in the upper crowns of trees. Correlation coefficients were calculated between mean compression wood content for trees and content at each of nine levels within trees. For all except the topmost level sampled, the coefficients were highly significant and ranged between +0.788 and +0.961, indicating strong uniformity of content within trees.

Larson, P.R. 1962. A biological approach to wood quality. Tappi 45(6): 443-448.

Considerable information concerning the variations in wood quality within and among trees and in relation to the environment has accumulated over the past 80 years; the practicing forester can find little to guide him in improving wood quality because of the many conflicting viewpoints presented. It is believed that most of the confusion in the literature results from attempts to relate wood quality directly to environmental influences. A more logical approach would be to relate wood quality to growth and development of the crown, for it can be shown that the external factors of climate and environment exert their influence directly on the growth of the crown and only indirectly on the growth and quality of the wood. The influence of the crown on wood growth can be demonstrated by considering a basic pattern of stem growth inherent in all trees.

Lavigne, M.B.; Donnelly, J.G. and Nostrand, R.S. van. 1987. A spacing trial in a precommercially thinned stand of black spruce at North Pond: Stemwood production during the first five years after thinning. Newfoundland For. Cent., Can. For. Serv., St. John's, NF; Inf. Rep. N-X-262, 16 pp.

Stemwood production rates per hectare and per tree for the five years immediately after thinning were compared among plots of various spacing in a young black spruce (Picea mariana (Mill.) B.S.P.) stand. Some thinned plots were fertilized with 200 kg/ha of nitrogen. Production rates per hectare were inversely related to width of spacing. By contrast, production rate per tree increased with increased spacing. Fertilization increased periodic stemwood production rates when done in combination with thinning.

Rates of stemwood production per hectare were positively correlated to foliar weights per hectare, but rates of stem wood production per kilogram of foliage were negatively correlated to canopy foliar weights. Higher rates of stemwood production per kilogram of foliage were due in part to less stem surface area per unit of foliar weight and not solely to increased availability to trees of light, mineral nutrients and water. The rate at which stem surface area per unit of foliar weight increased was reduced by thinning and by fertilization. This effect of thinning will be the most enduring one and therefore will have the greatest effect on final yields.

Lawrence, J.J. and Melvin, J.C.E. 1967. The status of forest insects and diseases following strip thinning of jack pine thickets in Manitoba. Dept. For. Rural Dev., For. Br., For. Res. Lab., Winnipeg, MB; Intr. Rep. MS-51, 6 pp.

The four diseases most commonly found were: a needle cast (Hypodermella ampla (Davis) Dearn.) of jack pine (Pinus banksiana Lamb.), a gall rust (Peridermium harknessii (J.P. Moore), a blister rust (Cronartium comandrae Peck) and a needle rust (Coleosporium asterum Syd.).

Results of the survey to date do not indicate any increase in the activity of insects or disease organisms which could be attributed to the mechanical thinning program.

Lee, R.G. 1986. Integrating tree-growing and wood utilization. Pp. 50-56 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

This paper addresses the problems of integrating tree-growing and wood utilization when the increasing proportion of juvenile wood reduces wood quality. The communication network involved with wood production is described, and barriers to effective communication are identified. Greater communication by foresters is deemphasized in favour of fundamental changes in the roles and responsibilities of foresters, investment analysts, and scientists. These institutional reforms are suggested as the best means for promoting feedback from wood utilization to tree-growing.

Leech, R.H. 1969. Response of a jack pine plantation to urea and potash fertilizers. Res. Br., Ont. Dept. Lands For. Tech. Ser. Res. Rep. No. 88, 44 pp.

Fertilization in southern Ontario by pack-tractor and trailer-spreader of a jack pine (Pinus banksiana Lamb.) plantation susceptible to wind-throw on a dry blow-sand high in phosphorus and low in nitrogen, with separate treatments of 200 lbs, 300 lbs, and 400 lbs per acre of urea, increased the circumference of co-dominant trees at breast height 76% over the controls, two complete growing seasons after fertilization; and the 300 lbs per acre treatment increased the volume growth of average thrifty trees 37% over controls and doubled cone production, four complete growing seasons after fertilization.

Fertilization with separate treatments of 200 lbs, 300 lbs and 400 lbs per acre of potassium sulphate was less effective in stimulating growth within the first two growing seasons, but six growing seasons after fertilization, the growth per cent of trees treated with potassium sulphate was 14% greater than the growth per cent of trees treated with urea.

On trees treated with either fertilizer, the mycorrhizal relationship was less vigorous than on control trees. This could indicate the resumption of non-mycorrhizal root growth on fertilized trees which would provide more support than mycorrhizal roots and so reduce the danger of wind-throw.

Long, J.N. and McCarter, J.B. 1985. Density management diagrams: A practical approach. in Proceedings-Growth and Yield and Other Mensurational Tricks: A Regional Technical Conference. Intermtn. Res. Stn., USDA For. Serv., Ogden, UT; 5 pp. (Published as General Technical Report INT-193).

Synopsis: Density management is the control of growing stock to achieve particular management objectives. The objectives of this paper are to briefly describe density management diagrams and to illustrate their potential with a diagram constructed for lodgepole pine (Pinus contorta Dougl.) in the central Rocky Mountains.

Low, A.J. 1974. Initial spacing in relation to establishment and early growth of conifer plantations. For. Comm. Res. Dev., United Kingdom; Pap. 110, 14 pp.

Synopsis: The effects of change in initial plant spacing are discussed in relation to the various establishment operations such as ploughing and planting. Different aspects of early crop performance are discussed.

Lowell, K.E. and Dwyer, J.P. 1988. Stem form and lumber yield: Long-term effects of thinning and pruning. North. J. Appl. For. 5: 56-58.

Though stem form and taper greatly affect the amount of recoverable lumber in a tree, little work has been conducted on the long-term effects of thinning and pruning on stem form and lumber yield. The work described suggests that long after treatment neither stem form nor the $bf/ft^3$ conversion ratio is affected by thinning and/or pruning. It is apparent that all of the merchantable volume increase induced by thinning will be recovered in the sawn lumber, but pruning does not appear to be a viable method for producing more cylindrical logs and increasing the conversion ratio.

Lowry, G.L. 1975. Black spruce site quality as related to soil and other site conditions. Soil Sci. Soc. Am. Proc. 39(1): 125-131.

Site factors were studied in relation to site index in 125 black spruce (Picea mariana (Mill.) B.S.P.) stands of eastern Canada. Site index was higher in the Continental than in the Atlantic Region, apparently due to differences in effective solar energy. In both regions site quality was related primarily to soil moisture and nutrients. Site index is better on freely drained, mesic mineral soils. These sites have modest humus accumulations. Soil analyses indicate that nitrogen and phosphorus limit tree growth over a broad range of site conditions. Few of the factors studied appear to have site index prediction value. However, many were suitable for site classification purposes. For extensive mapping of site productivity the primary framework should be landform and associated soils and geologic formations. Within this classification, moisture regime and nutrient regime may be included.

Lowry, G.L. 1972. Forest soil-site studies V. Black spruce productivity as related to soil and other site factors. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Rep. WR/44, 49 pp.

This report is based on observations from 125 black spruce (Picea mariana (Mill.) B.S.P.) stands located in the Boreal Forest of Canada from Newfoundland to western Ontario.

The results of this study clearly indicate that black spruce productivity is governed by three major factors: site quality, stand basal area and stand age. Maximum productivity was found in well stocked stands of high site index.

Site index was most closely associated with soil moisture and soil nutrients. In assessing nutrient status of this species, it appears that foliar analysis is more reliable than soil analysis. On the basis of the site-productivity relationships observed, it appears that the yield of many black spruce sites might be improved by: 1. Treatment to achieve full stocking 2. Forest fertilization 3. Swamp drainage.

In all cases the silvicultural manipulation should begin first on the highest quality sites nearest to the mill.

Lowry, G.L. and Avard, P.M. 1969. Nutrient content of black spruce and jack pine needles. III. Seasonal variations and recommended sampling procedures. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Pap. No. 10, 54 pp.

This third part of the current study of nutrient content of black spruce (Picea mariana (Mill.) B.S.P.) and jack pine (Pinus banksiana Lamb.) foliage is concerned with variations in nutrient element concentration and content associated with season. Data presented are from 20 spruce and 14 pine trees which were located in the Boreal forest near St. Michel des Saints, 100 miles north of Montreal.

Lowry, G.L. and Avard, P.M. 1967. Nutrient content of black spruce needles. II. Variations with crown class and relationships to growth and yield. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Tech. Rep. Ser. No. 523., Woodl. Res. Index No. 188, 20 pp.

The second part of the current study of nutrient content of black spruce (Picea mariana (Mill.) B.S.P.) foliage is concerned with differences in nutrient element content associated with crown class and as related to growth and yield. Data presented are based on 19 sample plots from 4 different areas and sampling periods.

Significant differences in potassium and magnesium content of black spruce needles were found between crown classes. No significant differences were found for foliar content of ash, N, P, or Ca.

Lowry, G.L. and Avard. P.M. 1965. Nutrient content of black spruce needles. I. Variations due to crown position and needle age. Pulp Pap. Res. Inst. Can., Montreal, QU; Tech. Rep. Ser. No. 425., Woodl. Res. Index No. 171, 20 pp.

Variations in the nutrient content of foliage may be due to such factors as needle age, crown position, crown class, and time of day or sampling season. This study was designed to determine the natural variation of black spruce (Picea mariana (Mill.) B.S.P.) foliage nutrient levels in a stand in the Boreal forest of eastern Canada. Standard laboratory procedures were followed to determine quantities of N, P, K, Mg, Ca and ash. With N and Mg, maximum concentrations were found in one-year-old needles, followed by a gradual decline in older needles. Highest concentrations of K and P occurred in the current foliage. Conversely, the lowest quantities of Ca and ash were found in the current needles followed by a gradual increase with age. Except for phosphorus, the individual trees ranked themselves in the same relative position for each of the nutrients tested. This was true regardless of the age or crown position of the foliage. Results showed that sampling current needles in the lower crown gave the least tree-to-tree variation.

Lozano, F.C. and Parton, W.J. 1988. Calibrating foliar nutrient standards for black spruce seed orchard management. Ont. Renew. Resour. Res., Ontario; Final Rep., 18 pp.

The Diagnosis and Recommendation Integrated System (DRIS) has proven superior to the critical value approach in the interpretation of foliar analyses for several crops. An investigation was conducted to determine the efficiency of the DRIS in improving the nutrient management of black spruce (Picea mariana (Mill.) B.S.P.) trees growing in recently established orchard sites in northwestern Ontario. Preliminary DRIS standards (norms) for the calculation of N, P, K, Ca and Mg indices were developed, and the initial testing of these norms was conducted.

Lozano, F.C. and Parton, W.J. 1986. Calibrating black spruce foliar nutrient standards for seed orchard management in northwestern Ontario. Univ. Toronto, Toronto, ON; 9 pp.

In this paper, we will present the initial results of a study designed to assess the nutrient status of black spruce (Picea mariana (Mill.) B.S.P.) growing in the Goodie Lake North Seed Orchard using the critical value approach and DRIS (the Diagnosis and Recommendation Integrated System). The seedlings used in this study were part of an on-going fertilizer rate trial in which nitrogen was applied at 7 different rates replicated in 9 blocks.

Lundgren, A.L. 1981. The effect of initial number of trees per acre and thinning densities on timber yields from red pine plantations in the Lake States. North Cent. For. Exp. Stn.,USDA For. Serv., St. Paul, MN; Res. Pap. NC-193, 24 pp.

Synopsis: An analysis of data for red pine (Pinus resinosa Ait.) plantations with initial densities (trees successfully established 5 yrs after planting) of 50-1600 stems/acre and subsequent thinnings to give 60-180 $ft^2$/acre residual basal area. Simulations of growth and yield are made using a program developed by the author. A series of graphs show the effect of thinning density on volume yields for different site indices.

The results show that initial density has a major effect on timber quality and quantity, with 200 stems/acre (500 stems/ha) thinned to a basal area of 120 $ft^2$/acre (27.5 $m^2$/ha) giving maximum volume yields in terms of board feet.

MacArthur, J.D. 1959. Growth of jack, red and Scots pine and white spruce plantations, 1922 to 1956 at Grand'Mère, Que. Pulp Pap. Mag. Can. 60: 15-18. (page 17 missing).

This report describes an experiment to compare the growth of jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.), Scots pine (Pinus sylvestris L.), and white spruce (Picea glauca (Moench) Voss) planted on abandoned farm land, which is representative of extensive areas of sandy, marine plain between the St. Lawrence River and the foothills of the Laurentian Uplands.

The results indicate that jack pine and red pine are both suited for planting in the area but that races of Scots pine and white spruce used in the experiment are not.

MacDougall, F.A. 1959. An example of potassium deficiency in a red pine plantation. Ont. Dept. Lands For., Div. Timber, Ontario; Tech. Bull. T. 17-3, 6 pp.

In the fall of 1956 a survey of the Parry Sound District was made to determine if red pine (Pinus resinosa Ait.) plantations on abandoned farm land were showing visual symptoms of nutrient deficiencies. A plantation in the Huntsville area was noted which exhibited poor height growth and discolouration of the foliage on many of the trees. To determine if these symptoms were caused by a nutrient deficiency, Professor K. A. Armson applied fertilizer to selected trees in the plantation in the spring of 1957. This report describes the method and results of these applications.

MacLean, D.A. and Wein, R.W. 1976. Biomass of jack pine and mixed hardwood stands in northeastern New Brunswick. Can. J. For. Res. 6(4): 441-447.

Biomass accumulation in 12 jack pine (Pinus banksiana Lamb.) and 11 mixed hardwood stands of fire origin ranging in age from 7 to 57 years is presented. Logarithmic equations relating aboveground tree, crown, and stem biomass to tree diameter at breast height are given for eight tree species.

MacLean, D.W. and Bedell, G.H.D. 1955. Northern clay belt growth and yield survey. Can. Dept. North. Affairs Natl. Resour., For. Br., For. Res. Div., Ottawa, ON; Tech. Note No. 20, 31 pp.

At the request of several pulp and paper companies, a test of the stand density index techniques was carried out during 1949-50 in the Nipigon area of northwestern Ontario. Preliminary results are encouraging although difficulties were encountered in obtaining a proper distribution of sample plots. To obtain more conclusive results a similar study was made in the Northern Clay Belt in 1951-52. The results are presented herein.

Maki, T.E. 1958. Forest fertilization possibilities in the United States. Pp. 12-19 in Forest Fertilization...A New Era. Am. Potash. Inst., 57 pp.

Synopsis: A discussion on erosion control, low-fertility sites, established stands, nurseries and Christmas tree operations, as they relate to fertilizers, is presented.

Malcolm, D.C. 1976. Site factors and the growth of Sitka spruce. Pp. 269-283 in Qualitative Studies of Site Factors and their Influence on Growth of Stands. Sect. 21, Working Grp. 5. Research on Site Factors. XV IUFRO Congr. IUFRO, Wageningen, NLD; 344 pp.

A major problem in site studies is the devising of suitable limitations to the study 'universe'. If it is inadequately defined little useful information may be obtained and if it is closely limited so that clear results emerge it may not be possible to extrapolate to other areas. An investigation of the site relationships of Sitka spruce (Picea sitchensis (Bong.) Carr.) stands which were of 'normal' growth and likely to attain utilisable sizes was begun in 1965 in selected areas in Scotland. In this study an attempt to overcome some of these difficulties was made by investigating productivity at two levels. Productivity measures and data analysis are discussed in detail. Data was analyzed in four ways: 1) calculation of a correlation matrix of the site data, 2) multiple regression analysis, 3) analysis of principal components, and 4) analysis of individual site factors.

Maloney, T.M. 1986. Juvenile wood--problems in composition board products. Pp. 72-74 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

Juvenile wood has known lower properties than mature wood. Extensive studies have not been made on the effect of juvenile wood on composition board product properties. A potential negative impact has been of concern in some studies. Considerable peeler core material containing large amounts of juvenile wood, however, have been used successfully in laboratory and pilot plant studies. Appropriate scientific studies are needed to determine if problems will occur with heavy use of juvenile wood in composition board. Considerable technology already exists to overcome some of the problems which logically could occur.

Manchester, D.F. and Naysmith, D., chairmen. 1981 in Proceedings of the jack pine utilization workshop. 26 pp.

Synopsis: The workshop was attended by professionals giving a 15 minute talk highlighting their experience with jack pine (Pinus banksiana Lamb.). Topics presented were growth characteristics, wood science, extractives, tree genetics and breeding, tree improvement, wood and pulp evaluation and a summary of the technical findings.

Manning, G.H. 1987. Impact of intensive forestry practices on net stand values in British Columbia. Nawitka Resour. Consult. Ltd., Victoria, BC; For. Resour. Dev. Agreement Rep. 014, 104 pp.

Synopsis: This report builds a trial from the treatment responses predicted by theory and demonstrated by research. It focuses on changes in the merchantable part of the stand, to further changes caused by applying treatments in operational conditions. The impact of intensive forestry practices in British Columbia are also described.

Marts, R.O. 1951. Influence of crown reduction on springwood and summerwood distribution in longleaf pine. J. For. 49(3): 183-189.

A study was made to determine the effect of reduction of crown size on tree growth, especially its effect on wood formation in longleaf pine (Pinus palustris Mill.). Severe and continued reduction of the lower part of the crown resulted in greatly reduced ring width in the lower part of the trunk. Springwood was reduced more than summerwood at the lower levels in comparison with wood formation in unmodified control trees. Higher in the trees near the lower limit of the crown, proportions of springwood and summerwood differed much less. The effect on springwood reduction in parts of the lower trunks of pruned tress was persistent for several years in the trees studied.

Mattice, C.R. and Curtis, F.W. 1978. Commercial strip thinning with a tree-length harvester. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-272, 23 pp.

The Timberjack RW-30 Tree-Length Harvester which was developed in Australia to thin plantations was introduced to Canada in the spring of 1973 by Eaton Yale Limited of Woodstock, Ontario.

To evaluate its effectiveness in thinning overstocked natural stands the Canadian Forestry Service arranged for a trial in a 48-year-old jack pine (Pinus banksiana Lamb.) stand 32.3 km southeast of Chapleau, Ontario. During the fall of 1973, 6.3 ha of forest were thinned in strips with a mean width of cut of 4.8 m and a leave-strip width of 5.2 m. The productivity of the harvester for the entire area as well as for trees of specific diameter was evaluated. Work studies were also conducted on the subsequent skidding operation. Revenues and costs were based on other experience with the harvester in order to predict the profitability for a logging contractor.

McIntosh, R. 1984. Fertilizer experiments in established conifer stands. United Kingdom; For. Comm. For. Rec. 127, 23 pp.

Results are presented from 55 fertilizer experiments in established Scots pine (Pinus sylvestris L.), Sitka spruce (Picea sitchensis (Bong.) Carr.) and Norway spruce (Picea abies (L.) Karst.) stands in upland Britain. Application of nitrogen consistently increased basal area increment in Scots pine stands for up to five growing seasons, the maximum response occurring at around 200 to 250 kg/ha N. Response to nitrogen decreased as stocking density increased and top whorl foliar nutrient concentrations gave a reliable indication of the degree of response to be expected. Results from the spruce experiments were more variable. Although responses to nitrogen, phosphorus and potassium were recorded, there was no consistent pattern of response in relation to site factors or foliar nutrient concentrations. Thinning immediately prior to fertilizer application significantly increased the fertilizer response of a pine stand but in three spruce experiments the effects of thinning and fertilizing were purely additive.

McKimmy, M.D. 1986. The effect of forest management practices on wood properties. Pp. 35-47 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

Two theses evaluating the effect of forest stand management on wood quality and wood strength are summarized. Various thinning regimes and fertilization had a significant influence on mechanical properties of wood (MOR - modules of rupture and MOE - modulus of elasticity) and annual ring density microcharacteristics determined by x-ray densitometry. Annual ring microcharacteristics had a highly significant influence on mechanical properties (MOR and MOE) of wood.

McMinn, R.G. 1986. Comparative productivity of seeded, natural and planted regeneration following various site treatments in white spruce clearcuts. Pp. 31-33 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as USDA Gen. Tech. Rep. PNW-194. May 1986).

Forest regeneration options are numerous. Stands may be restocked by natural regeneration, direct seeding or planting. The multiplicity of nursery stock types and site treatment methods increases the number of alternatives.

Regeneration strategy decisions depend on the interplay between two major factors- the productivity and the cost of regeneration options. This study indicates the relative productivity of a number of options.

The occurrence of seeded, natural and planted regeneration adjacent to each other in three clearcut sites 60 km east of Prince George, British Columbia, provided an opportunity to compare early white spruce (Picea glauca (Moench) Voss) growth rates following different methods of stand establishment. Several site treatment alternatives could be compared in each site. All sites had dense competing vegetation. Plantations ranged in age from 8 to 13 years.

McMullan, D. 1987. Designing Forest Management Regimes. Typewritten report of a talk prepared for the 1987 spring meeting of the Southern Interior Silviculture Committee (SISCO). 26 pp.

Highlights on maximizing wood product net profitability per hectare are described in overheads showing an example, and lists of goals and objectives.

Meng, C.H. 1981. Detection of stem form change after stand treatment. Can. J. For. Res. 11: 105-111.

Thinning and fertilization treatment effects on forest growth are usually evaluated in terms of volume increment. Measurements of growth response can be biased and misleading if treatment effects on stem form are not considered. A statistical approach, which enables detection of stem form changes accounting for them in a single stem volume equation, is demonstrated. This approach is applied to data obtained from a black spruce (Picea mariana (Mill.) B.S.P.) experiment and reveals statistically significant (at 5 % level of significance) changes in stem form following "heavy" thinning and fertilization.

Meylan, B.A. 1968. High longitudinal shrinkage in wood. For. Prod. J. 18(4): 75-78.

Synopsis: This paper discusses studies showing the relationship between longitudinal shrinkage, tangential shrinkage, and the mean microfibril angle in the $S_2$ layer of Monterey pine (Pinus radiata D. Don) and Jeffrey pine (Pinus jeffreyi Grer. and Balf.).

Miller, H.G.; Cooper, J.M.; Miller, J.D. and Pauline, O.J.L. 1979. Nutrient cycles in pine and their adaptation to poor soils. Can. J. For. Res. 9: 19-26.

Values for the various fluxes of nitrogen through the tree-soil system were calculated using models derived from measurements of rates of input, accumulation, and transfer in plots of 11-m-tall Pinus nigra var. maritima (Ait.) Melv. that were showing growth responses to varying rates of nitrogen fertilizer. As the result of continuing immobilization in trees and humus, growth of the unfertilized trees was declining and the trees were having to sacrifice older tissues to mobilize sufficient nitrogen for new growth. In the fertilized trees, there was similar mobilization but of excess nitrogen stored during the period that fertilizers were applied. Models of the flux of nitrogen, phosphorus, calcium, and magnesium at optimum growth showed that tight cycling and low rates of immobilization coupled with effective retention of relatively high atmospheric inputs, probably represent the adaptive mechanism that enables trees to thrive on soils low in potassium and magnesium. However, high rates of immobilization and low rates of atmospheric input relative to tree uptake mean that despite the maintenance of tight cycles, the trees continued to make significant demands on soil reserves of nitrogen, phosphorus, and calcium throughout their life cycle.

Miller, H.G.; Miller, J.D. and Cooper, J.M. 1981. Optimum foliar nitrogen concentration in pine and its change with stand age. Can. J. For. Res. 11: 563-572.

Levels of nitrogen in foliage associated with optimum growth of pine were determined in two hydroponic experiments in the glasshouse and two forest fertilizer experiments each designed to cover the full response range for Pinus nigra var. maritima (Ait.) Melv. During the years prior to canopy closure optimum nitrogen concentrations declined with the logarithm of tree weight, falling from 3.3% in very young seedlings to 1.5% in forest trees of 2.0-2.5 m in height. After canopy closure the level increased to about 2.0%. At all stages the concentrations associated with maximum height growth were less than those for maximum volume, weight or diameter increment. The relationships in the forest experiments, which are on sand dunes in the north of Scotland, could be improved by including factors of rainfall during the previous August and September and of temperature in June of the same year, but this did not alter the optima. It is concluded that for diagnostic purposes critical foliar nitrogen levels must be qualified by the age or developmental stage of the trees.

Mirov, N.T. 1956. Composition of turpentine of lodgepole x jack pine hybrids. Can. J. Bot. 34: 443-457.

Chemical composition of turpentines in lodgepole-jack pine hybrids was studied. When the two pines were artificially crossed, the F1 generation possessed turpentine in which the bicyclic terpenes of jack pine (Pinus banksiana Lamb.) dominated over the simpler, monocyclic terpene - phellandrene - of lodgepole pine (Pinus contorta Dougl.). Trees in a natural hybrid swarm also tended towards a predominance of the jack pine bicyclic terpenes.

Mitchell, K.J. 1969. Simulation of the growth of even-aged stands of white spruce. Sch. For., Yale Univ., New Haven, CT; Bull. No. 75, 48 pp.

Study of white spruce (Picea glauca (Moench) Voss) growing in central British Columbia. A mathematical model was developed which simulates the growth of stands in terms of crown expansion of individual trees. All simulated parameters are derived directly or indirectly from the height growth of dominant trees and the spatial distribution of individual trees. The model is designed to replace conventional yield tables and provide a tool for testing silvicultural practices and management plans.

Mitchell, K.J. and Kellogg, R.M. 1972. Distribution of area increment over the bole of fertilized Douglas fir. Can. J. For. Res. 2: 95-97.

Consideration is given to the distribution of growth increment at 6 points up the stem of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) 5 years after fertilization. The fully stocked stand, near Port Alberni B.C., was 49 years old with heights and diameters reaching 100 ft and 20 in. respectively when fertilized with 220 and 440 lb/acre of urea. No change of consequence occurred in tree form in the codominant and intermediate crown classes as a result of the volume response which was still evident, although greatly diminished, after 5 years. In dominant trees, however, cross-sectional area growth in the central third of the stem was less than the controls even though other parts of the bole showed a positive response which lasted until the 4th year. The net volume response was negligible. The estimation of volume response to fertilization in dominant trees from breast-height measurements should possibly be approached with caution.

Möller, C.M. 1947. The effect of thinning, age, and site on foliage, increment and loss of dry matter. J. For. 45: 393-404.

Synopsis: Beginning in 1925, a study was conducted to measure weight, area, and number of leaves by natural leaf fall per square metre of forest floor deposited. About 10 trays were distributed in each of 57 stands in various parts of Denmark in 1930, 1931, and 1932. These stands represented (1) different site-classes at the same age and grade of thinning, (2) different ages at the same site-class and grade of thinning, and (3) different grades of thinning of the same site-class and age.

This study suggests that a stand will always, under all circumstances, utilize the available amount of light to the fullest extent possible. Leaf area per hectare remains fairly constant, while the increment varies with site and age.

There is no apparent connection between quantity of leaves and growth (this was established only in association with thinning). Average volume of foliage is changed very little, if at all, by thinning. This is a result of the trees in the stand striving for full utilization of light.

Production does increase with increased stocking but only to the point where full occupancy of the site is obtained. Beyond this point increased density does not affect the amount of growth - only wood density. There will be a small number of relatively large trees at a low density ranging to a larger number of small trees at a higher density.

Moore, B. 1926. Influence of certain soil and light conditions on the establishment of reproduction in northeastern conifers. Ecology 7(2): 191-220.

The purpose of the experiments here described was to obtain further knowledge as to the influence of certain forest conditions on the reproduction of the more important northeastern conifers, particularly during the early stages covering the germination of the seed and establishment of the young seedlings. The aim was not only to find out how certain factors affect the establishment of reproduction under natural conditions, but to investigate the possibility of assisting reproduction by seed spots or by the exposure of the mineral soil under the forest. Attention was centred on the much discussed question of light versus shade, and on the influence of mineral soil as compared with humus of different kinds.

Morrison, I.K. 1974. Dry-matter and element content of roots of several natural stands of Pinus banksiana Lamb. in Northern Ontario. Can. J. For. Res. 4(1): 61-64.

The present paper is a companion to a previous report that described the content of dry matter and N, P, K, Ca, and Mg in 30- to 35-year-old stands of Pinus banksiana Lamb. in northern Ontario. The root systems of eight trees were excavated, weighed, and analyzed for chemical content. Using the regression-stand table method, dry-matter and nutrient content per hectare were estimated. On an areal basis, root weight of P. banksiana was lower than for stands of comparable age of other species located elsewhere. Likewise a smaller proportion of the total plant was in root with Pinus banksiana Lamb..

Morrison, I.K. 1973. Distribution of elements in aerial components of several natural jack pine stands in Northern Ontario. Can. J. For. Res. 3(2): 170-179.

Concentrations of N, P, K, Ca, and Mg were determined in aerial components of jack pine (Pinus banksiana Lamb.) trees growing in 12 stands, representing three age classes, two site classes, and two stocking intensities, all in close proximity on a coarse glacio-fluvial soil deposit, in northern Ontario. Element contents were estimated from these values in conjunction with dry matter functions. Regression equations relating logarithms of element content with logarithms of diameter at breast height were calculated. These were used in association with individual plot stand tables to give total weight per hectare of each element in the aerial parts of each stand. Converted to normal stocking, contents of all elements increased with increasing stand age. Over half of the aboveground N and P, but somewhat less than half of the aboveground K, Ca, and Mg occurred in crowns as opposed to stems in 65-year-old stands.

Morrison, I.K. 1972. Variation with crown position and leaf age in content of seven elements in leaves of Pinus banksiana Lamb. Can. J. For. Res. 2: 89-94.

Concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and manganese (Mn) were examined in September, 1969, in leaves of different ages from different parts of the crowns of twelve 30- to 33-year-old jack pine (Pinus banksiana Lamb.) growing in a natural stand on coarse glacio-fluvial soil in northern Ontario. Although considerable tree-to-tree variability did occur, it was not sufficient to obscure differences related to crown position and leaf age, except in the case of N, where no trends were demonstrable. Foliar P, K, and Mg concentrations were shown to decrease with increasing leaf age, whilst foliar Ca, Fe, and Mn concentrations were shown to increase. From top to bottom of the crown, foliar P, K, and Fe concentrations decreased, whilst Ca and Mn concentrations increased. For Mg, no trend relative to crown position was discernible. Coefficients of variation were calculated and compared as were numbers of sample trees needed for statistically reliable samples.

Morrison, I.K. and Armson, K.A. 1968. Influence of manganese on growth of jack pine and black spruce seedlings. For. Chron. 44(4): 32-35.

Analyses of foliage from natural stands of jack pine (Pinus banksiana Lamb.) and black spruce (Picea mariana (Mill.) B.S.P.) confirmed earlier observations that levels of manganese (Mn) were much higher in foliage of black spruce than in that of jack pine. Levels of Iron (Fe) in jack pine foliage were greater than in black spruce.

In a growth chamber experiment with spruce and pine seedlings and Mn supplied at 0, 0.1, 1, 10 and 100 ppm, both species grew best at the 0.1 ppm level and there was no evidence of difference in tolerance to high Mn levels. In this experiment, no marked species difference in foliar Mn concentrations was observed like that existing in natural stands. Possible reasons for this lack of difference are discussed.

Morrison, I.K. and Foster, N.W. 1979. Five-year growth in two nitrogen-phosphorus fertilization experiments in spruce and spruce-fir upland forest in northern Ontario. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-299, 15 pp.

Reports interim results from two factorial experiments involving applications of urea and triple superphosphate to 65-year-old black spruce (Picea mariana (Mill.) B.S.P.) and mixed spruce-fir stands on till upland sites in the Black Sturgeon Lake area of northern Ontario.

Morrison, I.K.; Hegyi, F.; Foster, N.W.; Winston, D.A. and Tucker, T.L. 1976. Fertilizing semimature jack pine (Pinus banksiana Lamb.) in northwestern Ontario: Fourth-year results. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-240, 42 pp.

In 1969, near Dryden in northwestern Ontario, Canada, nine fertilization experiments embracing a total of 301 measurement plots and 22,400 identified trees, were established in pure 55-year-old jack pine (Pinus banksiana Lamb.) forest of fire origin, on till and sandy outwash sites. Treatments evaluated were: combinations of N, P and K fertilizers (urea, triple superphosphate, and muriate of potash at various levels), N, P and Mg (supplied as magnesium oxide), N-sources (urea, urea-formaldehyde, ammonium nitrate and ammonium sulphate), time of application, split application, placement, and fertilization with thinning-from-below. These experiments were remeasured 4 years after establishment. Mean DBH, basal area, total and merchantable volume, and their increments were determined.

Morrison, I.K.; Swan, H.S.D.; Foster, N.W. and Winston, D.A. 1977. Ten-year growth in two fertilization experiments in a semimature jack pine stand in northwestern Ontario. For. Chron. 53(3): 142-146.

Two fertilization experiments were established in a 55-year-old relatively pure jack pine (Pinus banksiana Lamb.) stand on a Site Class III sandy site in northwestern Ontario. In the first experiment urea and ammonium nitrate at two levels of application were tested against controls. In the second experiment N, P, and K were applied in fixed mixture, with and without lime, at five levels of application plus control. These experiments were designed to test the response of seedlings to urea and ammonium nitrate, at equal rate of N, all other factors being constant.

Morrison, I.K.; Winston, D.A. and Foster, N.W. 1977. Effect of nitrogen, phosphorus and potassium fertilizers on growth of semimature jack pine forest, Chapleau, Ontario: Fifth-year results. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-258, 12 pp.

Reports interim results of a factorial experiment involving three levels of urea, three of triple superphosphate and three of muriate of potash applied to 45-year-old jack pine (Pinus banksiana Lamb.) forest on a Site Class I sandy outwash site.

Morrison, I.K.; Winston, D.A. and Foster, N.W. 1977. Effect of nitrogen fertilization and low thinning on growth of semimature jack pine forest, Chapleau, Ontario: Fifth-year results. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-267, 12 pp.

The effect of simultaneous urea fertilization and low thinning on jack pine (Pinus banksiana Lamb.) was tested in a factorial experiment in the Chapleau area of north central Ontario. The experiment, initiated in 1970, was in a 45-year-old, relatively thrifty, close stand of fire origin on a Site Class I sandy site. Typical of wild stands of the area, the experimental stand had no previous history of intermediate cutting. Three levels of N (O, 168 and 336 kg N/ha) supplied as urea were tested, as was thinning-from-below (conventionally by felling, and by silvicide injection) for a 20% BA reduction. After five years the following response variables were determined: mean DBH increment, BA increment, % BA growth, and total and merchantable volume increments.

Morrison, I.K.; Winston, D.A. and Foster, N.W. 1976. Urea dosage trial in semimature jack pine forest, Chapleau, Ontario: Fifth-year results. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-251, 8 pp.

Reports interim results of a trial involving five levels of urea (O-448 kg N/ha) applied to 45-year-old jack pine (Pinus banksiana Lamb.) forest on a Site Class I sandy outwash site.

Mullin, R.E. 1979. Plantation performance averages for jack pine. OMNR, Maple, ON; For. Res. Note. No. 20, 2 pp.

In graphical form this paper presents average survival and height growth of jack pine (Pinus banksiana Lamb.) in research plantations across Ontario.

Munro, D. n.d. A method of measuring and correlating the crown parameters of black spruce for predicting the foliage dry weight of trees and stands. Lakehead Univ., Thunder Bay, ON; 5 pp. (This is only part of the original thesis: pages 1 - 3 and pages 14 - 15)

The primary purpose of this study was to devise an accurate method of determining the foliage dry weight of black spruce (Picea mariana (Mill.) B.S.P.) in order to evaluate the foliage dry weight of mean trees and to predict that of stands. A secondary purpose was to describe the change in foliage dry weight that exists in natural black spruce stands with age, and to relate this corresponding change that occurs to the current annual increment.

Mustanoja, K.J. and Leaf, A.L. 1965. Forest fertilization research, 1957-1964. Bot. Rev. 31(2): 151-246.

This article reviews recent literature and proposes a framework for a forest fertilization classification system. The review is presented in two parts: the first deals with the analysis of the fertilization situation, the second with the measures taken on the basis of this analyses. The review is followed by a bibliography of forest fertilization literature published since 1956.

Myren, D.T. 1981. Use of Borax and sodium nitrite in an operational thinning of red pine in Ontario to prevent stump infection by Fomes annosus. For. Chron. 57: 284-285.

Both borax and sodium nitrite provided excellent protection of red pine (Pinus resinosa Ait.) stumps against Fomes annosus (Fr.) Karst. in an Ontario thinning operation. The contention that sodium nitrite which in the past failed to provide complete protection under some experimental conditions, would prove to be effective in operational use was validated. Since both chemicals provide protection, selection of a protectant for operational use is based on considerations other than effectiveness alone. Experiments were also conducted on jack pine (Pinus banksiana Lamb.).

Nicks, B.D. 1977. Growth and development of jack pine in the Atikokan district of northwestern Ontario. Univ. Toronto, Toronto, ON; 48 pp.

Growth and development of jack pine (Pinus banksiana Lamb.) was studied on three distinctly different soil types in the Atikokan District of northwestern Ontario. Cumulative height growth was found to be greatest on sandy loams underlain by medium sands, approximating low Site Class 1 in productivity. Cumulative height growth was intermediate on deep fine outwash sands which correspond to Site Class 2 for jack pine. Loamy sands underlain by bedrock at shallow depths produced growth approximating Site Class 3 for jack pine. Rapid initial volume growth on sandy loam/medium sand (SaL/mSa) sites suggests suitability for short-rotation pulpwood production, while moderate yet sustained volume increments on deep uniform fine sand (fSa) sites suggests 70-year sawlog rotations for jack pine. Shallow soils are considered incapable of sustaining mechanized timber harvesting.

Niznowski, G.P. 1988. Comparisons of growth and yield for planted lodgepole and jack pine near Longlac, Ontario. H.B.Sc.For. Thesis, Sch. For., Lakehead Univ., Thunder Bay, ON; 131 pp.

The height and volume growth of a 19 year old jack pine (Pinus banksiana Lamb.) plantation and an 18 year old lodgepole pine (Pinus contorta Dougl.) plantation were compared using regression analysis. Significant height and volume differences were obtained when early erratic growth below breast height was included. Measurements taken above breast height were less variable. The lodgepole pine was located on an esker and plots were stratified into two broad soil texture groups, sand and loam. The jack pine was located on a sandy relatively homogeneous glaciofluvial outwash sand. The volume growth of lodgepole and jack pine was somewhat better than the growth of the lodgepole on sand. However, the growth of lodgepole on loam was significantly better than lodgepole on the sand. Lodgepole pine and jack pine had similar relationships in the regression analysis that related volume to age, height, diameter at breast height (DBH), and stand density. Stand density did not explain a significant amount of variation in volume. The final regression equation explained 96 percent of the variation in volume using independent variables for age, height, and dbh.

Nostrand, R.S. van. 1979. Growth response of black spruce in Newfoundland to N, P and K fertilization. For. Chron. 55: 189-193.

Results are given for two NPK fertilizer trials established in 1967 and 1968 in 60-year-old black spruce (Picea mariana (Mill.) B.S.P.) stands in central Newfoundland. After nine years, replicated Trial 1 showed significant basal area and volume growth response over control for N, NP, NK and NPK treatments. N and NPK produced the greatest response where gains of 20 $m^3$/ha and 23 $m^3$/ha respectively were achieved after nine years. Similar results were obtained from non-replicated Trial 2 after eight years, where all treatments containing N produced approximately equal response. Maximum response in radial increment, measured from increment cores of sample trees, occurred four to six years after initial treatment. Generally, response was greater for dominant and co-dominant trees than for trees in the intermediate crown class.

Nostrand, R.S. van. 1975. Preliminary assessment of planted spacing trials in Newfoundland. Newfoundland For. Res. Cent., Can. For. Serv., St. John's, NF; Inf. Rep. N-X-133, 14 pp.

Black spruce (Picea mariana (Mill.) B.S.P.), Sitka spruce (Picea sitchensis (Bong.) Carr.), and balsam fir (Abies balsamea (L.) Mill.) were planted in three Nelder-design trials to test the affects of spacing and fertilization. After four growing seasons, the results of these tests showed no growth trends due to spacing, but there was a small overall positive response to long-lasting root-zone fertilizers.

Oliver, C.D. 1986. Silviculture and juvenile wood. Pp. 29-34 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

Timberland owners and forest product managers of the Pacific Northwest may both be facing a serious problem in the coming decades which can be resolved most favourably by an immediate, coordinated silvicultural and forest products effort. The problem is partly that the young plantations established during the past two decades at uniform spacings and ages generally have a core of wide-ring wood which is currently considered inferior quality. Another part of the problem is that when trees in these plantations reach about ten inches diameter, they often do not grow much larger for a long time unless some of the trees are removed by thinning. The third part of the problem is that there are more small-diameter trees in most regions of the United States now than during the past few decades and there is still much large diameter timber in the Pacific Northwest, so that there will be little demand for these small trees. Unless markets are developed for the wide-ring, small diameter wood which will be obtained in thinning these plantations, there will be little incentive for timberland owners to thin their stands and fewer trees will grow to become large diameter timber for processing in the future.

Oliver, W.W. 1979. Early response of ponderosa pine to spacing and brush: Observations on a 12-year-old plantation. Pac. Southwest For. Range Exp. Stn., USDA For. Serv., Berkeley, CA; Res. Note. PSW-341, 7 pp.

Ponderosa pine (Pinus ponderosa Laws.) was planted at five different spacings, from 6 x 6 to 18 x 18 feet, on a productive site in northern California. Spacing and brush effects on tree growth were evaluated both on plots where brush was allowed to develop and on plots kept free of brush. Competition between trees in brush-free plots began during the 8th year for trees spaced 6 x 6 feet and during the 10th year for trees spaced 9 x 9 feet. On several plots brush competition reduced tree diameters by the equivalent of nearly 3 years growth. These early results forecast the strong influence of spacing and brush on tree growth.

Olson, J.T.; Lundgren, A.L. and Rose, D. 1978. Equations for estimating stand establishment, release, and thinning costs in the Lake States. North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, MN; Res. Pap. NC-163, 7 pp.

Equations for estimating project costs for certain silvicultural treatments in the Lake States have been developed from project records of public forests. Treatments include machine site preparation, hand planting, aerial spraying, prescribed burning, manual release, and thinning.

Page, G. 1976. Quantitative evaluation of site potential for spruce and fir in Newfoundland. For. Sci. 22(2): 131-143.

This paper examines relationships between site index of black spruce (Picea mariana (Mill.) B.S.P.) and balsam fir (Abies balsamea (L.) Mill.) and soil and topographic characteristics in two areas of Newfoundland. One hundred and three quantitative variables were examined on 300 sample plots by multiple regression and principal component analysis. Equations, accounting for at least 60 percent of observed variation, were derived for predicting site index from soil and topographic characteristics. Soil moisture was most important, with soil nutrient status being of less, and topography of least, importance. Principal component analysis did not exceed multiple regression analysis in predictive ability, but was valuable in aiding biological interpretation of regression.

Patton, R.F. and Krebill, R.G. 1960. Deterioration of immature jack and red pine plantations in Wisconsin. Wisc. Agric. Exp. Stn., Univ. Wisc., Wisconsin; For. Res. Notes No. 64, 3 pp.

Synopsis: Since the early 1950's, a gradual premature decline of jack pine (Pinus banksiana Lamb.) and mixed jack pine and red pine (Pinus resinosa Ait.) plantations has been noticed on Plainfield sand in central and Ogema sand in northwestern Wisconsin. The most severely affected stands are 20-30 years old. Crown symptoms, spread and pattern of deterioration, and damage to the root systems are described.

Payandeh, B. 1986. Predictability of site index from soil factors and lesser vegetation in northern Ontario forest types. Great Lakes For. Cent., Can. For. Serv., Sault Ste. Marie, ON; Inf. Rep. O-X-373, 24 pp.

Data from 193 and 425 growth plots in the spruce-fir (Picea spp.-Abies spp.) and peatland black spruce (Picea mariana (Mill.) B.S.P.) forest types, respectively, of northern Ontario were used to establish relationships between site index and some of the soil factors, lesser vegetation and soil nutrient concentration. Stepwise multiple linear regression analysis and dummy variables were employed to express site index as a function of the above variables for each of the two data sets separately.

Results indicate poor correlation between site index and soil factors and lesser vegetation. Consequently, predictive equations based on these variables are of limited use. Many climatic and environmental factors other than soil factors and vegetation affect site productivity and plant growth. In addition, relationships between site productivity and soil factors and vegetation are far too complex and highly variable to be expressed or explained by simplistic relationships. Therefore, soil factors chosen for 'prime site' identification, such as texture, stone content, moisture regime and depth, may be poor predictors of site quality.

Payandeh, B. 1986. A simulation model for the economic evaluation of forest regeneration systems. Pp. 46-55 In Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as USDA Gen. Tech. Rep. PNW-194. May 1986).

This paper briefly discusses the main problems associated with evaluating long-term forestry investments involving risk and uncertainty. A computer model "FIDME" developed to evaluate such investments is then described. Input estimates for the model may be expressed by either point or subjective probability estimates. Simulated results will provide the probability that one investment might differ from others. Therefore, the forest manager will be able to choose, with a known degree of confidence, between investment alternatives. Three examples and model sensitivity are discussed.

Payandeh, B. 1978. A site index formula for peatland black spruce in Ontario. For. Chron. 54: 39-41.

Site index formulas were derived for peatland black spruce (Picea mariana (Mill.) B.S.P.) in northern Ontario based on stem analysis of 60 dominant and codominant trees. Non-linear regression analysis and a biological growth function were employed to express both height as a function of site index and stand age and also site index as a function of stand height and age. Analysis of results indicates that peatland black spruce has a different pattern of height growth than that shown by Plonski's site index curves, particularly for site indices less than 8 m and stands older than 80 years.

Payandeh, B. 1975. Evaluating the cost-effectiveness of planting and direct seeding of black spruce by simulation. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-238, 28 pp.

This paper describes an evaluation of the cost-effectiveness of direct seeding versus planting of black spruce, (Picea mariana (Mill.) B.S.P.), based on a recently developed simulation model that employs subjective probability estimates. Results of three examples based on estimates of current cost structure for both regeneration systems are presented and discussed.

Payandeh, B. 1975. Forest tree spatial patterns (1974). Pp. 37-46 in Ek, A.R.; Balsiger, J.W. and Promnitz, L.C., eds. Forest Modeling and Inventory. Selected Papers from the 1973 and 1974 Meetings of Midwest Mensurationists. Soc. Am. For.

Synopsis: Various distribution models are described and an aggregation assessment of the models is made. A study on the spatial patterns of the major timber types in northern Ontario is briefly described. Results demonstrate that spacial patterns of softwood trees in natural stands show varying degrees of clustering while random spacing is found in hardwood stands or the hardwood component of mixedwood stands.

Payandeh, B. 1974. Formulated site index curves for major timber species in Ontario. For. Sci. 20(2): 143-144.

Extension of the Richards growth model provides an excellent description of Plonski's site index curves for the major timber species (Picea mariana (Mill.) B.S.P., Pinus banksiana Lamb., Populus tremuloides Michx., Betula papyrifera Marsh., Pinus strobus L., and Pinus resinosa Ait.) of Ontario. Equations expressing height as a function of age and site index were derived based on a nonlinear regression analysis and least-squares approximation techniques. These equations facilitate computer processing and their first partial derivatives with respect to age provide approximate annual height growth estimates useful in the absence of localized growth data. The growth model employed here should be useful in describing site-index curves of other species, particularly those which have sigmoid and doubly asymptotic and polymorphic height-growth patterns.

Payandeh, B. n.d. Plant: A model for artificial forest regeneration in Ontario. Presented at IUFRO Forest Growth Modelling and Prediction Conference. 8 pp.

A simulation model was developed to help managers in Ontario solve forest renewal problems. The model treats the regeneration process as three separate, but interdependent phases of: 1) stock production, 2) storage, and 3) plantation management. During each phase, growth and survival of seedlings are simulated according to empirical submodels reflecting the effects of various biological factors as well as management options. Large data sets from several greenhouse/nursery operations and experimental plantations established in northern Ontario were used to construct predictive models. Such regression models were derived by first identifying factors affecting stock production and plantation performance via stepwise regression procedures, and then developing nonlinear models expressing seedling growth and survival as functions of time, management options and silvicultural practices. The model simulates various regeneration options according to the users choice. It compares and optimizes the results based on Regeneration Cost Effectiveness Index (RCEI). RCEI in effect combines the cost of production with growth, survival and the quality of the resulting "free-to-grow" stand. The model is written in FORTRAN and BASIC languages.

Perala, D.A. 1971. Growth and yield of black spruce on organic soils in Minnesota. North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, MN; Res. Pap. NC-56, 16 pp.

Synopsis: Describes the growth and yield relationship of Minnesota black spruce (Picea mariana (Mill.) B.S.P.) to site index, age, and basal density based on multiple regression analysis.

Phu, T.D. 1975. Potassium et magnesium: deux elements limitant la croissance en hauteur du pin rouge au Quebec. Can. J. For. Res. 5: 73-79. (French article, English abstract).

Relations between the site index of red pine (Pinus resinosa Ait.) and foliar concentrations in N, P, K, Mg, Ca, and Mn, the soil content in O.M., total N, available P, exchangeable K, $HNO_3$ extractable K, exchangeable Mg and Ca, and the percentage of silt plus clay of 23 sample plots on fluvio-marine or associated deposits in the St-Lawrence plain were studied. The site index varies between 28 and 42 at 20 years breast height (bh). There are significant and positive linear correlations between the site index and concentrations in K, Mg, and Ca in the needles. The linear correlation for Mn is significant but negative. However, multiple regression analysis indicate that only potassium and magnesium were significantly associated with the regressions. There are significant and positive linear correlations between the site index and the soil content in $HNO_3$ extractable K, exchangeable K and Mg. However, multiple regression analysis indicate that only $HNO_3$ extractable K has a significant contribution to variations of site index and the contribution of exchangeable Mg is almost significant at 0.05. There are also significant and positive linear correlations between the foliar concentrations of potassium and magnesium and the respective soil contents in $HNO_3$ extractable K and exchangeable Mg. Height growth of red pine in St-Lawrence plain is closely related to the nutrient status of potassium and magnesium in the sites under investigation.

Phu, T.D. and Gagnon, J.D. 1975. Nutrient-growth relationships in the Grand'Mere white spruce plantations before and after fertilization. Can. J. For. Res. 5: 640-648.

Relationships were studied between the concentrations of N, P, K, and Mg in the needles and the growth of planted white spruce (Picea glauca (Moench) Voss) on sandy marine and associated soils at Grand'Mere, Quebec. Multiple correlation analysis indicated a positive and highly significant relationship between K concentrations and growth expressed in terms of basal area and total volume. There was a negative relationship between P concentrations and both basal area and total volume. However, the coefficients of partial correlation for N, Mg, and P were low.

Significant increases in increments of basal area and total volume were obtained with 50 and 100 kg/ha K, 5 and 10 years after application. There was a moderate response in total basal area to rates of 57.5 and 115 kg/ha in the first five years only. No growth response was obtained with 45 kg/ha Mg for either period of observation. K, N, and Mg were applied as $K_2SO_4$, urea, and $MgSO_4$ respectively. No significant residual effects of N or K on foliar levels of N, K, and Mg could be established 10 years after treatment, although a marked and significant residual effect of Mg on foliar Mg concentrations could still be detected in the fertilized plots. Thus, K appeared to be the main element that limited growth of white spruce in these plantations.

Pienaar, L.V.; Shiver, B.D. and Grider, G.E. 1985. Predicting basal area growth in thinned slash pine plantations. For. Sci. 31(3): 731-741.

Long-term remeasurement data were used to evaluate different approaches to predicting basal area growth in thinned slash pine (Pinus elliottii Engelm.) plantation plots at four locations in South Africa. These data clearly indicated that a single projection model for both unthinned and thinned plantation plots, based on basal area and age at the start of the projection period, was inappropriate. Precision of the basal area projections were improved significantly when a measure of the thinning intensity was included in this model. Even better projections of basal area growth in thinned plots were obtained with an approach that utilized an index of suppression to modify the expected growth in comparable unthinned stands.

Popovich, S. and Houle, N. 1970. Etude preliminaire de trois plantations du Quebec (croissance, rendement et productivite). Min. Peches For., Serv. Can. For., Ste-Foy, QU; Rapport D'Inf. Q-F-X-3, 56 pp. (French report, English abstract).

The following report is a descriptive analysis of three plantations in Quebec. The chosen plantations, aged twenty, thirty and forty, are made up of the most common species used for reforestation (Picea mariana (Mill.) B.S.P., Pinus resinosa Ait., Picea abies (L.) Karst., Pinus banksiana Lamb., Larix laricina (Du Roi) K. Koch., and L. leptolepis (Sieb. & Zucc.) Gord.). An inventory permitted an analysis of their growth on different site types and also an evaluation of their yields. An aggregation of the results thus obtained were used to build productivity classes for red pine (Pinus resinosa Ait.) and white spruce (Picea glauca (Moench) Voss), based on unit standing volume as a productivity index. A sample tree stem analysis was also conducted for the Harrington plantation.

Porterfield, R.L. and Schweitzer, D.L. 1975. A quick and data-poor approach to evaluating precommercial thinning. J. For. 73: 771-773.

Economic break-even guidelines are combined with low-precision growth estimates to give a quick and inexpensive means for identifying precommercial thinning opportunities in lodgepole pine (Pinus contorta Engelm.).

Radwin, M.A. and Brix, H. 1986. Nutrition of Douglas-fir. Pp. 177-188 in Oliver, C.D.; Hanley, D.P. and Johnson, J.A., eds. Symp. Proc., Douglas-Fir: Stand Management for the Future. Coll. For. Resour., Univ. Washington, Seattle, WA; (Publ. as Inst. For. Resour. Contrib. No. 55. Only chapter 25 of the proceedings is photocopied).

This paper summarizes the basic nutritional information now available for Douglas fir (Pseudotsuga menziesii (Mirb.) Franco), with emphasis on recent findings and gaps in present knowledge. The paper is not an all inclusive literature review on the subject; rather it includes selected references to document the concepts presented.

Ralston, R.A. 1953. Some effects of spacing on jack pine development after 25 years. Lake States For. Exp. Stn., USDA For. Serv., St. Paul, MN; Tech. Notes No. 388, 1 pp.

Twenty five years after planting, jack pine (Pinus banksiana Lamb.) seedlings set out at a spacing of 6 x 6 feet have developed more satisfactorily than others planted at spacings of 4 x 4 and 8 x 8 feet in a test established as an administrative study on the Huron National Forest on a site fairly representative of the poorer, sandy planting "chances" on the outwash plains of northern Lower Michigan. A summary of measurements taken in 1936 and 1951, which show several differences in growth attributable to spacing, is listed herein.

Rennie, P.J. 1972. Forest fertilization in Canada. Can. For. Serv., Buenos Aires, AG; 28 pp.

This review outlines the main Canadian forest fertilization programs conducted by industry, provincial governments, the universities and the federal Canadian Forestry Service. Both commercial and research and development programs are described with sufficient on the Canadian forest and its environment to provide perspective. The development of activities up to the present-day is traced and the probable future trends and emphases are discussed.

Rennie, P.J. 1963. Methods of assessing site capacity. Commonw. For. Rev. 42(4): 306-317.

Increasing pressure on land for agricultural, forestry and urban usages has prompted progressive communities to integrate these demands to get the maximum value from a given area. An essential precursor of such integrated development, however, is an ability to appraise land for different types of utilization. This paper critically reviews the various methods used for the complex task of assessing forest-site capacity.

Methods may be direct or indirect. Direct mensurational techniques record a growth characteristic of interest and by their objectivity are of fundamental and long-standing importance. Indirect procedures employ one or other of the related criteria-climate, ground vegetation, soil properties, foliar characteristics and ecological site mapping. For their reliability they depend on the validity of the relationship between growth and the criterion selected. Their use may permit growth to be more easily measured and more reliably sustained.

Consideration of the methods as applied in various countries to nursery, newly forested and natural-forest areas suggests greater emphasis be placed on the selection and refinement of criteria more intimately related to physiological growth processes, and more attention be focused on basic studies in soil-forest relationships.

Righter, F.I. 1922. A more scientific method of experimental thinnings. J. For. 20: 280-281.

Synopsis: A method is described, for conducting and evaluating thinning experiments, which conforms to the principle of scientific experimentation. In scientific experimentation, it is customary to either subject similar things to different treatment, or dissimilar things to the same treatment. According to the author, a thinning experiment does neither.

It is suggested that when conducting a thinning experiment, trees in the control plot should be marked as if an actual thinning was being done (without actually performing the thinning). In such an experiment, growth percent and periodic growth percent figures will not be misleading because the figures for each plot will be based on equal or nearly equal volumes initially.

Riley, L.F. 1973. Operational trials of techniques to improve jack pine spacing. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Inf. Rep. O-X-180, 26 pp.

Operational trials were carried out to determine both the best stage in stand development for conducting spacing treatments and the most efficient method of achieving desirable spacing in young jack pine (Pinus banksiana Lamb.) stands. The trials were conducted in three age classes (9, 22, and 33 years) and two methods of treatment were tested in each. Time-motion studies were made to determine the factors affecting productivity and to indicate possible improvements in techniques. Cost comparisons were made between treatments, and for each age class benefit/cost calculations were employed to indicate the state at which spring operations can be expected to yield the greatest net returns. The actual cost of spacing was lowest in the 9-year age class, and in spite of the longer time to harvest, the calculated benefit/cost ratio was highest for this class. In the 9-year age class treatment was more efficient with powered brushsaws than with Sandvik axes; in the 22-year age class chainsaws were more efficient than axes; and in the 33-year-old stand, treatment with hypo-hatchets was more efficient than felling with hand tools.

Riley, L.F. 1973. Silviculture treatment of seeded stands. Pp. 139-155 in Direct Seeding Symposium.

Density reduction, both precommercial and commercial, can be biologically desirable and economically feasible if conducted at the proper time in the life of the stand, which is generally at an early age. In recent years mechanical, precommercial, strip thinnings have been the most common but such methods result in cleared corridors with dense, intervening residual strips of live trees. Research results have indicated that strip thinning is less desirable biologically than individual tree spacing. Currently, considerable work is being done in the development of more efficient mechanical row thinning equipment. Aerial strip thinning using herbicides has been tried with uncertain results to date.

A recent commercial row thinning in semimature jack pine (Pinus banksiana Lamb.) was economically successful. A new harvester which can double as a thinner will be tested to determine if commercial thinning can be efficiently mechanized in Boreal Forest stands which have arisen following fire or seeding.

Roberge, M.R. and Knowles, R. 1965. Available nitrogen in a black spruce humus fertilized with urea. Pulp Pap. Res. Inst. Can., Montreal, QU; Tech. Rep. Series No. 430., Woodl. Res. Index No. 172, 28 pp.

In 1961, an experiment was begun at Baie Comeau, Quebec, to investigate the effects of urea fertilization on tree growth, on humus decomposition and on liberation of nutrients. Twenty-four months after this treatment was applied, samples of humus from untreated and from urea-treated plots were incubated with urea or ammonium carbonate for 42 days. In all, 1100 samples of humus were incubated and 13,000 analytical determinations were made. Two days after the start of the incubation, no urea could be detected in the humus. Its maximum recovery in an available ammonium form was however registered only after three days. This recovery was higher in the field-treated than in the field-untreated humus and decreased from the F2 layer (89%) to the L layer (75%). Thus immobilization of the added nitrogen was surprisingly low (11-25%) and increased only slightly during the remaining incubation. The hydrolysis of urea to ammonium was accompanied by a rise in pH of 1.2 to 1.8 units. This permitted the accumulation of nitrate in the field treated humus. Nitrite concentrations however were always found to be lower than 0.2 ppm. The results obtained with ammonium carbonate were generally the same as those with urea.

Robertson, A. 1986. Boreal energy plantation R & D with Salix species. Pp. 27-30 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as Gen. Tech. Rep. PNW-194. May 1986).

In the last decade short-rotation willow (Salix) plantations have become an attractive, high-yielding, biomass energy source in cool climatic regions. Preliminary results at Pasadena, Newfoundland show that 28.5 t DM/ha/yr with an energy equivalent 513 GJ/ha, can be achieved in the boreal forest region. While high yields are expected in the more productive forest areas of Newfoundland, the paper stresses the need for biogeographical and biometeorological research that will examine the fundamental problems of establishing energy plantations in areas characterized by thin soils and a high mean annual wind speed.

Roche, L. 1970. Forest genetics in eastern Canada: The needs and the opportunities. Pp. 27-41 in Besley, L. and Balloch, E.A., Chairman. Proceedings of the Seminar on Forest Genetics and Forest Fertilization. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; 81 pp.

Synopsis: This section of the paper covers the minutes of Dr. Roche's presentation. Topics presented are forest genetics, geographic variations and forest tree seed. Description of slides presented are also given along with the discussion following the presentation.

Roe, E.I. and Stoeckeler, J.H. 1950. Thinning over-dense jack pine seedling stands in the Lake States. J. For. 48: 861-865.

Synopsis: After fires, jack pine (Pinus banksiana Lamb.) can reproduce in very dense stands. These stands often stagnate or at best their growth is slow. This study was undertaken to determine when thinnings should be conducted and to what extent. This thinning experiment, designed to answer the question of spacing and age, was established in 1941. At 5 years of age, blocks within the stand were thinned to 4 x 4, 6 x 6, and 8 x 8 foot spacings. Subsequent thinnings were carried out at ages 10, 15 and 20 years. Results suggest that in order to minimize damage from snow, stands should be thinned at very early ages. To date a 4 x 4 foot spacing seems superior to heavier thinnings.

Roeser, J. 1932. Thinning jack pine in the Nebraska sand hills. J. For. 30: 918-924.

Two remeasurements of thinning plots in the Nebraska National Forest jack pine (Pinus banksiana Lamb.) plantations of 1903 indicate that the heavily thinned stand with 696 trees per acre has made a gain in volume of 58 per cent compared with the unthinned stand with 2098 trees per acre. The moderately thinned stand with 1,480 trees had made a 41 per cent gain, and the lightly thinned with 896 trees a 31 per cent gain. Both the accelerated growth and the stronger wood structure, as results of thinning, suggest the advantage of heavy thinning to concentrate the growth on a smaller number of individual trees which will have a more nearly sufficient supply of moisture.

Rowe, J.S. 1962. Soil, site and land classification. For. Chron. 38(4): 420-432.

Forest management is a kind of land management, and the forester's attention is increasingly drawn to the physical land base from which forestry values derive.

Various approaches to the inventory of forest land are discussed: through soil classification with its inherited agronomic background, through site classification whose yardstick is productivity, through classification using few or many environmental factors, and through classification based on morphological features of the land itself.

Purpose is implicit in all classifications and different purposes lead to different classifications. It is suggested that forestry purposes are best served by a land classification which initially breaks the landscape pattern into geomorphological parts, each relatively constant as to surface materials. These can be further divided into relatively homogeneous forest-land patches or ecosystem units, the basis for study and prediction of productivity. As a means of reducing complexity, land inventory needs to be placed within a geographic framework of regions or zones.

Rudolf, P.O. 1951. Stand density and the development of young jack pine. J. For. 49: 254-255.

What effect does stand density have upon the development of young jack pine (Pinus banksiana Lamb.) stands? It is known in a general way that over-dense stands result in spindly trees and early mortality from competition, and that marked understocking results in heavy branching and poor form. However, there is little exact information as to the actual development of young stands established at known densities. Yet such information is of importance for handling both natural and planted stands. For this reason, in the spring of 1941 the Lake States Forest Experiment Station established a plantation on the Mauistee National Forest near Wellston, Mich., in which jack pine was planted at five different spacings. Results at the end of nine growing seasons are reported here.

Sadiq, R.A. and Smith, V.G. 1983. Estimation of individual tree volumes with age and diameter. Can. J. For. Res. 13: 32-39.

Even though invention of high-precision equipment has reduced measurement errors associated with the estimation of heights of standing trees, height estimation is still an expensive and time-consuming operation. At times it is difficult to determine especially in dense forests or in forests located in hilly terrain. The present study advocates a volume-age-diameter function to estimate volumes of individual trees. The technique presented here circumvents measurement of tree heights through the use of age which, however, restricts the application of the function to plantations or forests whose age is predetermined. Analyses with stem-analysis data from red pine (Pinus resinosa Ait.) plantations of southern Ontario indicate that the function estimates tree volumes more accurately than the standard methods commonly used.

Salonius, P.O.; Fisher, R.A. and Mahendrappa, M.K. 1982. An alternative method of measuring fertilizer effects in forest stands. Can. J. For. Res. 12: 146-150.

In natural stands, variations in growth rates between plots before treatment due to variable stocking, variable population structure, and site differences often preclude the assessment of growth response to fertilizer treatment by conventional plot comparison. An alternative methodology is described, using growth for a black spruce (Picea mariana (Mill.) B.S.P.) stand in a pretreatment period as the standard against which growth following treatment is compared for each tree. The results of this comparison on treated and control plots are then related to each other to evaluate growth response to fertilizer treatment. Methods for extracting meaningful fertilizer response data are suggested for experiments which are in progress or are completed but not yet harvested.

Sandvik, M. 1986. The impact of artificial regeneration on rotation age in Norway spruce and Scots pine areas in Norway. Pp. 10-14 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as USDA Gen. Tech. Rep. PNW-194. May 1986).

The possibilities for natural regeneration are considered related to site quality and altitude. The most fertile sites have to be artificially regenerated. On medium and poor sites natural regeneration may be achieved. The effect on rotation age reaches from -6 to +40 years compared to artificial regeneration. Lodgepole pine (Pinus contorta Dougl.) survived and grew better than Scots pine (Pinus sylvestris L.) at high altitudes.

Schantz-Hansen, T. 1934. Some results of thinning 27-year old jack pine. J. For. 29: 544-550.

The investigator in this instance found large-scale thinnings in young jack pine (Pinus banksiana Lamb.) stands economically unsatisfactory since the resulting product could not be marketed. Volume growth in itself was not stimulated sufficiently to justify thinning, however, since the growth was accumulated on fewer trees in the case of the thinned plots as compared to unthinned plots, there resulted individual trees of higher quality and more marketable sizes.

Schenk, J.A.; Dosen, R.C. and Benjamin, D.M. 1957. Noncommercial thinning of stagnated jack pine stands and losses attributable to bark beetles. J. For. 55: 838-841.

The primary objective of the experiments described here was to determine whether noncommercial thinning could be conducted in stagnating jack pine (Pinus banksiana Lamb.) stands in central Wisconsin during the summer months with a laissez faire attitude towards the slash without suffering an economic, barkbeetle-caused loss in the residual stand.

Schlaegel, B.E. 1975. Yields of four 40-year-old conifers and aspen in adjacent stands. Can. J. For. Res. 5(2): 278-280.

Volume and dry-weight yield comparisons of 40-year-old planted red pine (Pinus resinosa Ait.), jack pine (Pinus banksiana Lamb.), white spruce (Picea glauca (Moench) Voss), black spruce (Picea mariana (Mill.) B.S.P.), and a naturally regenerated aspen (Populus tremuloides Michx.) sucker stand show that red pine has the highest yields and black spruce the lowest. Volume yields of aspen, jack pine, and white spruce are similar, but weight yields of white spruce are much less than weight yields of either aspen or jack pine. It is recommended that yield comparisons within and between species should be done on a weight as well as a volume basis because large differences in densities can occur.

Schmidt, M.G. and Carmean, W.H. 1987. Jack pine site quality in relation to soil and topography in north central Ontario. Typewritten paper prepared for submission to Can. J. For. Res. 35 pp.

Site index for jack pine (Pinus banksiana Lamb.) was determined by stem analyses using dominant and codominant trees on each of 99 site plots located in mature, well-stocked, even-aged jack pine stands. Plots located on four major glacial soil groups showed a wide range of site index within each soil group. Separate multiple regression analyses showed that site index was significantly related to different soil and topographic features for each soil group: a) morainal soils shallow to bedrock, $R^2=0.83$; b) deep morainal soils, $R^2=0.65$; c) outwashed glacial sands, $R^2=0.65$; and d) glacial lacustrine soils, $R^2=0.75$. The results indicate that site quality for jack pine on each of these four general soil groups is related to soil features associated with the quantity and quality of soil most favourable for root development. Results are illustrated by trend graphs, and site index prediction tables are given for each of the four soil groups.

Schnekenburger, F. 1983. Fertilization and thinning affect snow damage in jack pine. H. B. Sc. For. Thesis, Sch. For., Lakehead Univ., Thunder Bay, ON; 47 pp.

In the summer of 1979 a fertilizer and thinning trial was established in a young stand of jack pine (Pinus banksiana Lamb.). In the winter of 1980/81 several plots of the trial were severely affected by snow damage. Statistical analysis revealed that the damage was concentrated on those plots that had been treated with nitrogen fertilizer. It was postulated that an increase in needle elongation and shoot elongation in response to the nitrogen fertilization were causes of the increased snow damage. To determine the needle response to fertilization, a sample of 1980 foliage was collected from randomly selected trees on each plot of the trial. Needle length was measured and an analysis of variance was performed. To determine shoot response, tree heights, both before and after initial treatments, were measured for a random sample of trees on each plot. These values were subjected to an analysis of covariance.

Results indicated that needle elongation was significantly greater on the plots that received nitrogen fertilization. Height growth was not significantly increased by fertilization or thinning. Thus, the increase in snow damage on the fertilized plots was apparently the result of an increase in needle elongation stimulated by the nitrogen fertilization. A delay in the stem growth response to fertilization may have compounded the problem.

Scott, S.L.; Barker, J.E.; Morrison, I.K. and Foster, N.W. 1982. Basic density of jack pine wood influenced by fertilization and thinning. For. Chron. 58: 44-46.

Basic wood density was measured at eight bole positions within and below the green crown in a jack pine (Pinus banksiana Lamb.) fertilization and thinning trial near Chapleau, Ontario. Analysis showed a 6% reduction of average density in wood laid down during the first 5 years following treatment. A significant height x fertilizer interaction was noted during the same period indicating that bole density gradients specific to fertilized trees should be used to calculate biomass gains from fertilization if substantial underestimates of response are to be avoided. The portion of the bole where the wood changed most rapidly from low density, juvenile-type to higher density mature-type wood appeared to be just beneath the base of the green crown.

Selin, L.O. 1977. Field experiences in pre-commercial thinning, planting and container growing of northern softwoods. USDA For. Serv. Rep. NE-29. (From Proceedings of the Symposium on Intensive Culture of Northern Forest Types, pages 179 - 181, complete article not on file).

In preparation for intensive logging mechanization and for the subsequent silvicultural treatments of clear cut areas the Woodland Division of Georgia-Pacific Corporation started a pre-commercial thinning trial in young softwood and mixed wood stands during the spring and early summer of 1970. Pre-commercial thinnings were intended to be a backbone of a large scale silvicultural system which relied upon natural regeneration of clearcut areas and early thinning of subsequent pre-merchantable stands. It was hoped that through this cycle of treatments the average diameter growth occurring on individual stems could be more than doubled in comparison to natural stands. It was also automatically assumed that the treatments would make considerable shorter rotations possible.

Only a few years later when the techniques of growing viable seedlings in containers had been fully tested and proven, it came obvious that even further reductions in length of rotations were possible for a private landowner who was willing to risk a modest investment on productive greenhouse facilities. As a result of these observations the Woodland Division of this corporation initiated in the spring of 1974 a comprehensive program on intensive silvicultural practices which consisted of raising container-type planting stock in large numbers and hand planting it on clearcut sites which in turn had been prepared for planting by heavy mechanized crushing and rolling equipment. It is expected that pulpwood rotations of twenty-five to thirty years and sawlog rotations of forty-five years are possible within the scope of this approach.

Senft, J.F.; Quanci, M.J. and Bendtsen, B.A. 1986. Property profile of 60-year-old Douglas-fir. Pp. 17-28 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

A profile of wood properties in 60-year-old Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) is presented in relation to juvenile wood characteristics and their potential effect on wood products. Juvenile wood is further discussed with its associated problems in wood products.

Shea, S.R. 1981. Intensive management of jack pine. OMNR, Toronto, ON; 43 pp.

In this report, I focused on the biological constraints on the development of an intensive management strategy for jack pine (Pinus banksiana Lamb.). Intensive management is discussed from a conceptual viewpoint because a data base for the growth and yield characteristics of plantation during jack pine is still relatively small. However, there is a considerable amount of biological information on the species and even though the growth and yield information for development of precise intensive management schedules is deficient, broad schedules could be outlined. Consequently, I have attempted to outline how the current data could be used or improved by relatively short term research, but I have also suggested an outline for a longer term research program.

Shea, S.R. and Armson, K.A. 1972. Stem analysis of jack pine (Pinus banksiana, Lamb.): Techniques and concepts. Can. J. For. Res. 2(4): 392-406.

Detailed stem analysis data are presented for 6 trees which ranged in age from 44 to 68 years and grew on a range of soils which varied primarily in soil texture. The use of measures of specific growth such as current annual height increment, Type 3 ring width sequences and specific volume increment is discussed in relation to supply of raw materials to the tree. The change in form of tree crown, as reflected by Type 1 ring width sequences is related to the other measures of specific growth. The use of selected parameters of tree growth in relation to tree development and its possible application in silviculture is discussed.

Sjolte-Jorgensen, J. 1967. VI. The economic influence of spacing. Int. Rev. For. Res. 2: 43-94. (Only pages 79-83 available).

Synopsis: Financial returns of Picea abies (L.) Karst. with different spacings are calculated. A summary of growth factors with respect to spacing is provided.

Skeates, D.A. 1979. Discontinuity in growth potential of jack pine in Ontario: A 20-year provenance assessment. For. Chron. 55: 137-141.

The province of Ontario is divided into three major jack pine (Pinus banksiana Lamb.) populations as a result of grouping 12 seed sources on the basis of growth characteristics, 20 years from sowing. Migration following glaciation is postulated as a cause of population differentiation.

Growth of trees from the 12 stands was positively but weakly correlated with growing degree days. However some northern sources flourished in southern plantations. Consistent growth differences were found between some geographically close sources, justifying further, more intensive sampling to identify the most productive sources of seed for each of the major areas of jack pine silvicultural activity in the province.

Smissaert, C. 1988. Quality control in precommercial thinning. Silvic. Mag. 3(1): 10-11.

Our contractual experiences with numerous forest agencies has led us to compare and contrast assessment procedures, while developing operational procedures of our own. This paper will discuss our post assessment criteria and procedures, including sections on density parameters and qualitative evaluations. The duties of the "tree crop" come under examination and guidelines for assessment are suggested.

Smith, C.R.; Johnson, J.D. and Riley, L.F. 1986. Economics of precommercial thinning in jack pine. Pp. 34-45 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as Gen. Tech. Rep. PNW-194. May 1986).

The economics of precommercial thinning in jack pine (Pinus banksiana Lamb.) for sawlog production is analyzed with data produced to date from two precommercial thinning trials undertaken in northern Ontario in 1970. Overstocked conditions in the unthinned stands make diameter and density projections imprecise; however, preliminary indications are that neither of these two thinnings will provide attractive returns. Higher densities in the unthinned stands at rotation more than offset the economic contribution of the higher average diameters of the thinned stands. Further measurements are required to predict the development of the unthinned stands more precisely. Optimum estimates of diameter and density development indicate that the stand thinned at age 9 years will provide a positive return to investors requiring a real rate of return at 4%. The stand thinned at age 9 years yields a higher return than the stand thinned at age 22 years because of the high treatment cost of the 22-year-old thinning.

Smith, D.M. 1968. Wood quality of loblolly pine after thinning. For. Prod. Lab., USDA For. Serv., Madison, WI; Res. Pap. FPL-89, 12 pp.

In this exploratory study of wood properties two treatments were sampled on loblolly pine (Pinus taeda L.) These are: Treatment 1 - At 9 years of age (winter of 1953-54) remove all but 100 crop trees per acre; prune every 3 years to no more than 50 percent of total height. Treatment 4 - No thinning at age 9. At 12 years of age (winter of 1956-57) select 100 crop trees per acre; thin stand to leave 85 square feet of basal area per acre, favouring crop trees; no pruning.

Smith, J.H.G. 1986. Use of wider spacings to reduce costs and increase volumes and values grown. B.C. Lumberman. 43-52.

Timber managers who want to optimize use of scarce resources (planting stock and labour) should grow large, valuable trees by taking advantage of abundant land and recognizing excessive supplies of small trees. The 16 prescriptions offered here, if understood and implemented fully, could greatly improve the long-run health of the Canadian forest industry.

Smith, J.H.G. 1959. Comprehensive and economical designs for studies of spacing and thinning. For. Sci. 5(3): 237-245.

This report outlines the information required from studies of spacing and thinning, reviews available experimental designs, and states some advantages of using a fixed number of trees, individually described trees, and a moderate size of isolation area or "surround". An experimental design that has been employed in several projects is described to illustrate an inexpensive and effective approach to establishment of studies of spacing and thinning.

Smith, J.H.G. 1958. Better yields through wider spacing. J. For. 56(7): 492-497.

This paper will examine several elements of wood quality as well as important profit and cost factors, and will show how forest managers should plan now for quick growth and high quality. Discussions are based on Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) but can be extended to other conifers.

Smith, N.J. and Brand, D.G. 1987. Compatible growth models and stand density diagrams. Pp. 636-643 in Ek, A.R.; Shifley, S.R. and Burk, T.E., eds. Forest Growth Modelling and Prediction. Volume 2. Proceedings of the IUFRO Conference. Soc. Am. For. Publ. No. SAF-87.12.

A stand average growth model based on the self-thinning rule is developed and used to generate stand density diagrams. The model is tested on plantation data from 15 remeasured red pine (Pinus resinosa Ait.) permanent sample plots. For total stem volume (cubic meters/ha.) versus numbers of stems per ha. the slope was 1.39 and the intercept 10350 cubic meters/ha/tree. Incipient mortality occurred at a relative density (RD) of 0.04, maximum current annual increment at 0.51 RD and maximum mean annual increment at 0.82 RD. Diameter distributions were 'recovered' from any point on the diagram using the Weibull distribution.

Smith, V.G. 1983. Assessment of bias in the 1973 Forest Resource Inventory on the Spruce Falls Power and Paper Company Limited concession. Fac. For., Univ. Toronto, Toronto, ON; 16 pp.

Synopsis: The purpose of this study is to assess the bias that is introduced into the 1973 Forest Resources Inventory (F.R.I.) for the Spruce Falls Power and Paper Company concession from each of these sources; 1) photo interpretation, 2) yield tables, and 3) growth estimation.

The objectives for the assessment are to provide standards against which new yield tables can be compared and also to provide a measure of reliability for the age class projections that are made in looking at various forest management options.

Smith, V.G. 1983. Black spruce empirical yield tables. Fac. For., Univ. Toronto, Toronto, ON; 26 pp.

Current methods of estimating black spruce (Picea mariana (Mill.) B.S.P.) growth and yield in the clay belt region of northern Ontario are based on normal yield tables developed by Plonski (1960).

Experience has shown that these yield tables consistently over-estimate present gross volume in stands, while growth projections are inaccurate due to unexplained changes in site index and stocking levels over time.

This study develops empirical growth and yield tables for claybelt black spruce that more accurately estimate present and future yields. Accuracy has been improved through use of permanent sample plot data gathered by the Spruce Falls Power and Paper Company from the 1930's to present, supplemented by 1/10-acre plots measured in June and July 1982.

Smith, W.R. and Briggs, D.G. 1986. Juvenile wood: Has it come of age? Pp. 5-11 in Robertson, D., Proc. Coord. A Technical Workshop: Juvenile Wood - What Does it Mean to Forest Management and Forest Products? For. Prod. Res. Soc., Soc. Am. For., Madison, WI; 81 pp.

The percentage of juvenile wood contained in wood products has the potential to increase dramatically. As this occurs lower quality material is expected which will bring lower revenues and reduce wood product marketability. This paper discusses juvenile wood, why it is of concern, what is being done about it and some thoughts on what needs to be done.

Smithers, L.A. 1957. Thinning in lodgepole pine stands in Alberta. Can. Dept. North. Affairs Natl. Dev., For. Br., For. Res. Div., Ottawa, ON; Tech. Note No. 52, 26 pp.

The Forestry Branch, as early as 1937, undertook a program of research designed to develop practical methods of thinning lodgepole pine (Pinus contorta Dougl.) stands. The purpose of this Technical Note is to present tentative conclusions on thinning carried out in Alberta, and in some cases to indicate the necessity for further research.

Smithers, L.A. 1954. Thinning in red and white pine stands at Petawawa forest experiment station. Can. Dept. North. Affairs Natl. Dev., For. Br., For. Res. Div., Ottawa, ON; Silvic. Res. Note No. 105, 52 pp.

Investigations on the effects of thinning red (Pinus resinosa Ait.) and white pine (Pinus strobus L.) stands have been underway for a period of 30 years at the Petawawa Forest Experiment Station. It has been found that one or two very heavy thinnings made late in the stand life do not substantially increase the total production and gross increment may be reduced by excessively heavy thinnings. The growth of selected crop trees can be stimulated greatly by intensive thinning practice and the length of time required to produce merchantable sizes of trees may be appreciably reduced. Suggested thinning regimes for various sites are presented as guides, but it is emphasized that the success of thinning treatments will depend to a large extent upon the judgment of the forester in selecting crop trees and providing them with optimum growing conditions.

Solomon, D.S.; Hosmer, R.A. and Hayslett, H.T. 1987. Fibre handbook: A growth model for spruce-fir and northern hardwood forest types. Northeast. For. Exp. Stn., USDA For. Serv., Broomall, PA; NE-RP-602, 19 pp.

A matrix model, FIBRE, has been developed to provide the forest manager with a means of simulating the management and growth of forest stands in the Northeast. Instructional material is presented for the management of even-aged and multi-aged spruce-fir, mixedwood, and northern hardwood stands. FIBRE allows the user to simulate a range of silvicultural treatments for a variety of species compositions growing on different sites. The internal structure of the model is defined and explanations on the use of FIBRE are offered. Examples of input, interim procedures, and final output are shown. The species available in the model are: Abies balsamea (L.) Mill., Picea mariana (Mill.) B.S.P., Picea rubens Sarg., Picea glauca (Moench) Voss, Tsuga canadensis (L.) Carr., Thuja occidentalis L., Acer saccharum Marsh., Acer rubrum L., Betula alleghaniensis Britton, Betula papyrifera Marsh., Fagus grandifolia Ehrh., Fraxinus americana L., Populus tremuloides Michx., Betula populifolia Marsh., Acer pensylvanicum L., Prunus pensylvanica L.P., Fraxinus nigra Marsh., Larix laricina (Du Roi) K. Koch., and Pinus strobus L.

Spurr, S.H. 1955. Soils in relation to site-index curves. Soc. Am. For. Proc. 19: 80-85.

Site-index relationships developed from temporary sample plot data and conventional techniques are apt to contain errors that mitigate against their use in studies involving soils-growth relationships. Height-growth curves should be developed from actual measured growth which can best be obtained from permanent sample plot data which can also be developed from stem analysis and internode measurement techniques. Height growth data for Douglas-fir (Pseudotsuga menzeisii (Mirb.) Franco) and red pine (Pinus resinosa Ait.) are used to illustrate this principle.

Spurr, S.H. and Hsiung, W. 1954. Growth rate and specific gravity in conifers. J. For. 52: 191-200.

Few subjects in forestry have attracted so much interest over so long a period of time as the influence of growth conditions on specific gravity of dry wood substance. Few subjects are so little understood by present-day foresters. Despite the large amount of research in the field, there is apparently no adequate summary of the findings. Wood technologists and silviculturists have approached the same problem with different points of view, different techniques, and frequently, different conclusions.

This paper, based upon a thorough study of the literature and upon original investigations on jack pine (Pinus banksiana Lamb.) is an attempt to clarify this important subject insofar as conifers are concerned.

Steinbrenner, E.C. 1970. Weyerhaeuser's forest fertilization program. Pp. 42-60 in Besley, L. and Balloch, E.A., Chairman. Proceedings of the Seminar on Forest Genetics and Forest Fertilization. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; 81 pp.

Synopsis: This section of the paper covers the minutes of Dr. Steinbrenner's presentation. Topics presented were forest fertilization in the Northwest, equipment used for application, and some results from experimental trials of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco). Throughout the presentation slides were used and described in the text; the discussion following the presentation is include herein.

Steneker, G.A. 1969. Strip and spaced thinning in overstocked jack pine and black spruce stands. Dept. Fish. For., For. Br., Winnipeg, MB; Inf. Rep. MS-X-16, 14 pp. (Project MS-134).

Fifteen-year results of strip and spaced thinning in 1949 in dense 30, 40 and 60 year old jack pine (Pinus banksiana Lamb.) stands and a dense 58 year old black spruce (Picea mariana (Mill.) B.S.P.) stand have shown that jack pine responds to thinning at all ages tested. Black spruce showed a markedly greater response to thinning than even the youngest jack pine stand. Thinning to a 7x7 foot spacing in the youngest jack pine stand and the black spruce stand resulted in a loss in total volume production, probably as a result of inadequate utilization of the site. Thinning to a 9x9 foot spacing in the 60 year old stand increased total volume production by about 30 percent. Production on the strip-thinned plots was quite similar to that on the unthinned plots in all stands. Merchantable volume production on thinned plots was higher than on unthinned plots in all stands. An evaluation of thinning costs and revenues in 1949 and potential revenues in 1964 indicated that only thinning the 60 year old jack pine stand to a 9x9 foot spacing was a profitable undertaking.

Stiell, W.M. 1986. Development of white spruce plantations at the Petawawa National Forestry Institute, Chalk River, Ontario. Pp. 15-20 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as USDA Gen. Tech. Rep. PNW-194. May 1986).

Growth and yield characteristics are reported for white spruce (Picea glauca (Moench) Voss) plantations established 1922 to 1940, mostly on old field sites. Main research was in thinning and the development of yield tables for unmanaged stands, based on site index and initial planted spacing. A widespread root rot, Polyporus tomentosus Fr. has caused significant mortality in some plantations.

Stiell, W.M. 1986. Fifteen-year growth of tamarack planted at six spacings on an upland site. Petawawa Natl. For. Inst., Can. For. Serv., Chalk River, ON; Inf. Rep. PI-X-62, 22 pp.

Development of tamarack (Larix laricina (Du Roi) K.Koch) established at six spacings, from 1.25 x 1.25 m to 4.25 x 4.25 m, on an upland site, is reported to age 15 years from planting. Data were collected by remeasurement of permanent sample plots located in each spacing, which included observations of dbh, height, crown size and stem taper. Comparisons between spacings for individual tree growth were made for a subsample representing the modal dbh class present at the time of the first measurement (nine years from planting). Per hectare development was obtained from stand tables complied for the individual plots. Relations of stand values to spacing were determined by stepwise regression. The combined effect of height and spacing on various parameters was demonstrated.

Stiell, W.M. 1970. Thinning 35-year-old white spruce plantations from below: 10-year results. Can. For. Serv., Ottawa, ON; Publ. No. 1258, 16 pp.

A thinning experiment to examine the relation of stand growth to density of residual growing stock was established in 1958 at the Petawawa Forest Experiment Station in plantations of white spruce (Picea glauca (Moench) Voss) about 35 years old growing on sandy old-field sites. In a treatment series sample plots were thinned from below to basal area levels of 80, 110, and 140 square feet per acre, and a control plot was left unthinned. Series were replicated in plantations established at spacing of 5 x 5 feet and 7 x 7 feet. In 1968 the plots were remeasured and thinned again to the prescribed basal area. Thinning to basal areas in the range 100 to 140 square feet per acre could be carried out, without reducing growth, in plantations of the age and condition described for 1958, and would yield 3 to 8 cords per acre, depending on intensity of cut.

Stiell, W.M. 1968. Spacing and survival tables for plantation. Tree Plant. Notes. 19(3)

These tables concern three expressions of plantation density-spacing distance, number of trees per acre, and percent survival (tables 1-5). The tables have been useful for both research and management since they convert simply field and office data to that of density required. They can be applied appropriately wherever density conditions are reasonably uniform.

A short explanatory note accompanies each of the five tables.

Stiell, W.M. 1964. Twenty-year growth of red pine planted at three spacings. Can. Dept. For., For. Res. Br., Ottawa, ON; Publ. No. 1045, 24 pp.

Plantations of red pine (Pinus resinosa Ait.), established at the Petawawa Forest Experiment Station in 1941 in sandy soil of an old field at spacings of 7'x 7', 10'x 10', and 12'x 12', were examined in 1960. Detailed measurements were made to determine tree height and diameter at 5 year intervals, and observations of form-class, crown size, and branch numbers and diameters were recorded in 1960. The data are presented on the basis of average tree growth and per acre development for each spacing. Larger crowns, thicker branches, greater breast height diameters, and lower form-class were associated with wider spacing. Average height was the same at all spacings.

Stiell, W.M. 1955. The Petawawa plantations. Can. Dept. North. Affairs Natl. Resour., For. Br., For. Res. Div., Ottawa, ON; Tech. Note No. 21, 46 pp.

This report presents some information on plantations established between 1922 and 1940 at the Petawawa Forest Experiment Station. Specific data on such points as the influence on survival of class of stock, planting method, and competition from natural growth; relative growth of species on a given site; age when merchantable material is first produced; and comparative development of different spacings.

Stiell, W.M. and Berry, A.B. 1977. A 20-year trial of red pine planted at seven spacings. For. Manage. Inst., Can. For. Serv., Ottawa, ON; Inf. Rep. FMR-X-97, 25 pp.

Development of red pine (Pinus resinosa Ait.) planted at seven spacings, from 1.2 x 1.2 m to 4.3 x 4.3 m is reported for stand ages 10 to 20 years. The pattern of crown and stem growth was followed for 10 consecutive remeasurements of a subsample of individual trees, and stand development was determined from 13 permanent sample plots remeasured at 5-year intervals. Precise data are presented, including volumes calculated from stem measurements of trees in the subsample to take into account changes in form. The combined role of height and spacing in controlling various growth features is demonstrated, and regressions derived for predictive purposes.

Stone, E.L. 1958. A look ahead at forest fertilization research... A new silviculture tool. Pp. 38-47 in Forest Fertilization...A New Era. Am. Potash. Inst., 57 pp.

Forest nutrition investigations involve one or more of three procedures: (1) Recognition and characterization of fertility status, (2) modification of fertility status, and (3) study of the forest as a nutrient system. These procedures are discussed.

Swan, H.S.D. 1970. Economics of forest fertilization and other considerations with respect to intensive forest management in eastern Canada. Pp. 60-80 in Besley, L. and Balloch, E.A., Chairman. Proceedings of the Seminar on Forest Genetics and Forest Fertilization. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; 81 pp.

Synopsis: This section of the paper covers the minutes of the last presentation of the proceedings given by Mr. Swan. Topics presented were cost of fertilization in relationship to gain of wood volume. Examples are given of treatments as well as views regarding the industry's raw material supply. The discussion following the presentation is reported herein.

Swan, H.S.D. 1970. Relationships between nutrient supply, growth and nutrient concentrations in the foliage of black spruce and jack pine. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Pap. No. 19, 46 pp.

A sub-irrigation sand culture apparatus was used to grow black spruce (Picea mariana (Mill.) B.S.P.) and jack pine (Pinus banksiana Lamb.) seedlings for 26 weeks in a greenhouse. Essentially the study consisted of five black spruce and five jack pine experiments. In each of these ten experiments the supply of one of five macro-nutrients (nitrogen, phosphorus, potassium, magnesium and calcium) was varied from nil to a relatively high level, while all the other twelve essential elements were supplied at levels known to be sufficient for satisfactory growth. Each treatment was replicated once. A partial harvest (four seedlings from each pot) was made after 16 weeks and the final harvest was made at 26 weeks. Immediately prior to the final harvest all pots were photographed in black and white and in colour. Average dry weights per seedling were determined and the needles were analyzed for nitrogen, phosphorus, potassium, magnesium and calcium. The data obtained permitted curves showing the relationship between seedling dry weight and foliar nutrient concentration to be plotted. The responses to increasing supplies of the limiting element were much more pronounced at 26 weeks than at 16 weeks. Based on the growth/foliar nutrient concentration curves and experience gained over the past ten years with the use of foliar analysis as a diagnostic tool, standards by which to evaluate the results of foliar analyses are tentatively suggested for black spruce and jack pine.

Swan, H.S.D. 1968. Fertilizers, their role in reforestation. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Pap. No. 9, 11 pp.

A distinction is drawn between naturally and artificially regenerated stands; the case for the use of fertilizers is stronger with respect to the latter. The role of fertilizers in seed orchards, forest nurseries, young plantations and semi-mature stands is discussed.

Swan, H.S.D. 1967. The fertilization of man-made forests. Presented at World Symposium on Man-Made Forests and Their Industrial Importance. Food Agric. Org., United Nations, Silv. Sect. II, Rome, IT; 13 pp. (Position Paper).

The scientific use of fertilizers in forestry, with special reference to man-made forests, is discussed. Trees, like any other crop, require a balanced diet of thirteen essential elements for satisfactory growth. Many large tracts of forest soil consist chiefly of nutrient deficient siliceous sands. Only by the intervention of man can these natural soil deficiencies be corrected. The importance of being able to diagnose deficiencies correctly is stressed. It is suggested that the diagnostic problem can be solved by making use of visual symptoms, soil and foliar analyses and soil bio-assays. The use of each of these diagnostic techniques is discussed in relation to man-made forests. Mineral deficiencies may be corrected by the direct application of either organic or inorganic fertilizers.

Swan, H.S.D. 1966. Studies of the mineral nutrition of Canadian pulpwood species. The use of visual symptoms, soil and foliage analyses and soil bio-assays for the determination of the fertilizer requirements of forest soils. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Tech. Rep. Ser. No. 464, Woodl. Res. Index No. 179, 11 pp.

The use made of visual symptoms, soil and foliage analyses and soil bio-assays in an investigation of the fertilizer requirements of two Canadian jack pine (Pinus banksiana Lamb.) stands is described. Each of the four techniques made some contribution to the solution of the diagnostic problem but all, except perhaps the bio-assays, gave somewhat ambiguous results. The bio-assay has considerable merit as a simple and direct method of evaluating the fertility of a forest soil. It is very unlikely that field responses will be as great as those obtained in the bioassays (50:1) but, as a fertilizer trial in one of the stands indicates they may be expected to be substantial.

Swan, H.S.D. 1965. Reviewing the scientific use of fertilizers in forestry. J. For. 63(7): 501-508.

Wood is becoming an increasingly scarce commodity in many parts of the world with wood deficits imminent before the end of the century. Trees require a balanced diet of six macro-nutrients (nitrogen, phosphorus, potassium, magnesium, calcium and sulphur) and seven micro-nutrients (boron, copper, zinc, iron, manganese, molybdenum and chlorine) for healthy vigorous growth. Many soils provide insufficient supplies of these elements and only by the intervention of man can the deficiencies be corrected. Successful fertilization depends on correct diagnosis of deficiencies by study of visual symptoms, soil and foliage analyses, and bio-assays. Aerial fertilization costs $10 to $30 per acre and the response may last from five to 40 years. The potential gains are more immediate and of greater magnitude than those achieved by most other forms of intensive silviculture. Fertilizers are not a panacea but can yield both biological and financial advantages. Use of fertilizers in forestry is well established in many parts of the world.

Swan, H.S.D. 1965. Studies of the mineral nutrition of Canadian pulpwood species. Phase II. Fertilizer pellet field trials. 1959-1963. Final report. Pulp Pap. Res. Inst. Can., Montreal, QU; Tech. Rep. Ser. No. 405, Woodl. Res. Index No. 163, 33 pp.

Twenty-six 1,000-tree field plots were established in order to determine if placement of a urea-formaldehyde/phosphorus fertilizer pellet beneath young conifers, at time of out-planting, increased the growth of the trees. Species planted were: Picea glauca (Moench) Voss, Picea mariana (Mill.) B.S.P., Picea abies (L.) Karst., Picea rubens Sarg., Pinus banksiana Lamb., Pseudotsuga menziesii (Mirb.) Franco, Larix eurolepis Henry, and Larix decidua Mill. Unpelleted trees survived very slightly better than pelleted trees, but the overall averages differ by less than 3% and it may be concluded that, in these trials, pelleting did not have a substantial effect on survival, which was, on the whole, satisfactory regardless of treatment.

The concept of a slowly soluble, non-toxic, fertilizer pellet which can be placed in the planting hole appears to be sound, but the pellets tested in these trials were too small to provide the tree with sufficiently large supplementary supplies of nitrogen and phosphorus to increase growth for more than a short period (2-5 years).

Swan, H.S.D. 1963. Studies of the mineral nutrition of Canadian pulpwood species. Phase II. Fertilizer pellet field trials. Progress Report No. 4. Pulp Pap. Res. Inst. Can., Montreal, QU; Woodl. Res. Index No. 140, Res. Note No. 38, 4 pp.

In 1959, twenty-two 1,000-tree field trials were established in order to determine if placement of a urea-formaldehyde fertilizer pellet beneath young conifers, at time of out-planting, increased growth of the trees. As reported in the first three Progress Reports the 1959, 1960 and 1961 data show that modest (approximately 10%) increase in average leader length were associated with pelleting. This fourth and penultimate report summarizes the 1962 growth and survival data. It shows that the tapering off in the response to the pellets, noted previously, is more pronounced with bottom pelleting than with side pelleting.

Swan, H.S.D. 1962. The mineral nutrition of the Grand'Mére plantations. Pulp Pap. Res. Inst. Can., Montreal, QU; Tech. Rep. Ser. No. 276, Woodl. Res. Index No. 131, 14 pp.

The history of, and the research studies made in, the Grand'Mere, P.Q. plantations are reviewed. The plantations consist principally of: Picea glauca (Moench) Voss, Picea abies (L.) Karst., Pinus sylvestris L., Pinus banksiana Lamb.,and Pinus resinosa Ait. Attention is drawn to the fact that, almost from the first, the area was recognized as a problem area and that today 74% of the plantations are classified as "heavily deteriorated" and only 3% as "thrifty".

The interim results of a current investigation, designed to study the nutritional status of the vigorous and the stunted trees, are reported. These lend support to the view that potassium and, to a lesser extent, nitrogen deficiencies are the principal factors limiting growth.

Swan, H.S.D. n.d. The mineral nutrition of forest trees. Pp. 1-9 Presented at Seminar on Silvicultural Research. Pulp Pap. Res. Inst. Can., Montreal, QU; 9 pp.

Synopsis: The function of various elements vital to plant growth are briefly outlined. Diagnosis of mineral deficiencies and its correction through fertilizer applications are discussed.

Tamm, C.O. 1958. Forest fertilization in Europe...Its research and practices. Pp. 2-11 in Forest Fertilization...A New Era. Am. Potash Inst., 57 pp.

Synopsis: A discussion on nutrient cycling and availability is presented, with emphasis on German and Belgium trials.

Tappeiner, J.C.; Bell, J.F. and Brodie, J.D. 1982. Response of young Douglas-fir to 16 years of intensive thinning. Sch. For., For. Res. Lab., Oregon State Univ., Corvallis, OR; Res. Bull. 38, 17 pp.

A 20 year old Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) stand in the Oregon Coast Range was thinned from about 1,700 to about 350 trees per acre. Average net periodic cubic-volume growth was strongly influenced by thinning regime, varying from about 220 cubic ft/ac/yr (heavy thinning age 30) to over 550 cubic ft/ac/yr (controls age 23). Evaluation of volume, diameter, and basal area growth indicates that young Douglas-fir on productive sites (site index 160 to 170 ft at 100 years) are extremely adaptable and will respond to frequent thinnings of various intensities.

Thomson, A.J. and Barclay, H.J. 1984. Effects of thinning and urea fertilization on the distribution of area increment along the boles of Douglas-fir at Shawnigan Lake, British Columbia. Can. J. For. Res. 14: 879-884.

The effects of fertilization and thinning of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) on the distribution of area increment along the bole were assessed using radial growth measurements 6 and 9 years after treatment. Within treatments, the average area increment per tree was linearly related to diameter at breast height, and this relationship was used to evaluate the effects of treatment on growth rate. Fertilization had the greatest effect on average area increment, and for a particular fertilization regime, thinning increased the response.

Timonen, M. and Varmola, M. 1986. Experiences and research on yield impacts of artificial regeneration at high latitudes in Finland. Pp. 5-9 in Murray, M., ed. The Yield Advantages of Artificial Regeneration at High Latitudes. Proceedings, 6th International Workshop on Forest Regeneration. Pac. Northwest Res. Stn., USDA For. Serv.; Sch. Agric. Land Resour. Manage., Univ. Alaska-Fairbanks, Portland, OR; 60 pp. (Published as USDA Gen. Tech. Rep. PNW-194. May 1986).

Artificial regeneration has been used in Finnish Lapland from the 1910's. It is normally used on sites where natural regeneration will not succeed. The most promising results have been achieved when converting thick-moss spruce stands to pine stands. However, extreme conditions have caused partial or total failures especially on high altitudes.

Towill, W.D. and Siczkar, L.A. 1988. Hogarth Plantations. Pp. 8-10 Notes from Great Lakes Forests and Soils Field Tour, Thunder Bay, ON, Aug. 23-25, 1988.

Synopsis: The Hogarth Plantation history and soil and site type are briefly described. A list of establishment and tending treatments for the Hogarth Plantations is provided.

Towill, W.D. and Siczkar, L.A., 1988. Spacing plantation at the Thunder Bay Forest Station. Pp. 11-13 Notes from Great Lakes Forests and Soils Field Tour, Thunder Bay, ON, Aug. 23-25, 1988.

Synopsis: The black spruce (Picea mariana (Mill.) B.S.P.), white spruce (Picea glauca (Moench) Voss), red pine (Pinus resinosa Ait.), and white pine (Pinus strobus L.) spacing trials at the Thunder Bay Forest Station are briefly described. The most recent sampling was conducted in 1983. Statistics on height, diameter, crown dimensions and volume are presented.

Udell, R.W. and Dempster, W.R. 1987. Predicting the growth and yield of regenerated lodgepole pine. B.C. Lumberman. 71(2): 48-60.

Champion Forest Products (Alberta) Ltd. has been in operation for thirty years. The management plan, up until now, has looked only to the end of the first rotation when calculating allowable annual cut. Even though the success rate of the company's reforestation program is close to 100 percent, a downfall in allowable cut was predicted as the regenerated stands were brought into the yield prediction model. Nevertheless, field observations and preliminary data analysis seemed to indicate much higher growth rates than those of natural stands. The challenge, then, was to develop a practical system to reliably predict the future yield of regenerated stands on the Champion forest Products (Alberta) Ltd. Forest Management Area. Lodgepole pine (Pinus contorta Dougl.) was the target species for the investigations. There is overwhelming evidence to suggest that the future yield of regenerated stands will surpass that of natural stands of lodgepole pine. Techniques are available to predict these yields with some confidence. The challenge is to husband these young forests through to maturity.

Urie, D.H. 1971. Estimated groundwater yield following strip cutting in pine plantations. Water Resour. Res. 7(6): 1497-1510.

Ground water recharge balances were determined under 40-acre blocks of a jack pine (Pinus banksiana Lamb.) plantation in northwestern lower Michigan during the 4 years following the removal of 50 % of the trees in clear-cut strips. Analyses were made by graphical interpretation of diurnal fluctuations and by use of finite difference equations. In the numerical method, weekly water table elevation measurements over each 40-acre block were used to determine water table convexity, which was then linearly related to the groundwater inflow-outflow balance. Results from both methods of analysis showed the effect of strip cutting as increased groundwater yields. Estimates of water yield by the two methods differed primarily as a result of poor estimates of net evaporative loss from the saturated zone using the graphical method. Three other tests of cutting effects on groundwater recharge supported the budget estimates of treatment effect. Approximately 3 inches per year of additional water was produced as a result of the strip cut during the first 4 years after cutting. The numerical analysis showed that the amount of treatment effect decreased rapidly over this period.

Vassov, R. and Baker, W.D. 1988. Pre-commercial thinning of jack pine. Northwest. Ont. For. Tech. Dev. Unit, OMNR, Thunder Bay, ON; Tech. Rep. 12, 25 pp.

The pre-commercial thinning of jack pine (Pinus banksiana Lamb.) is an important silvicultural control method over the density and development of natural or artificially seeded stands. Compared to unthinned controls, growth responses from pre-commercial thinning of jack pine have resulted in higher diameter increments, lower total volume and basal area per hectare, higher merchantable volume per hectare and lower mortality, but no difference in height growth. Thinning is most economically feasible when undertaken once the lower branches begin to die (ages 6 to 12 years) on site class 1 and possibly on the upper half of site class 2 stands where sawlogs are the end product. Motor manual thinning using brush-saws, or as an alternative, manual thinning with axes and sandviks are the most efficient means of pre-commercial thinning. Manual thinning provides the opportunity for crop tree selection which is one of the most important considerations of the thinning operation. Crop trees must be dominant, within the prescribed spacings, have low taper, small branch diameters and be relatively free from disease and damage.

Vézina, P.E. 1965. Growth and yield of three pulpwood species in Quebec as affected by stocking. Pulp Pap. Mag. Can. 66(11): 483-493.

This study presents the results of growth and yield analyses of tree data observed in a number of pure even-aged stands of Abies balsamea (L.) Mill., Picea mariana (Mill.) B.S.P. and Pinus banksiana Lamb. in three areas of Quebec. Several equations for estimating pulpwood growth and yields based on variations in stocking, average dbh, and height were developed by multiple regression methods. The influence of stocking on average stand height and volume by average dbh is shown for the three species considered. It is noted that variations in stocking can greatly affect the height-dbh relationship, and this in turn can influence the efficiency of mechanized logging operations.

Vézina, P.E. 1964. An analysis of measures of density in even-aged balsam fir and jack pine stands. For. Chron. 40(4): 474-481.

The concept of stand density in relation to thinning is examined and its development over the years is discussed. Present difficulties of objectively measuring stand density are recognized and probable future trends towards the development of better formulae to express stand density are outlined. Three stand variables, used as expressions of stand density, were tested in crown closure simple regressions in even-aged, unmanaged stands of balsam fir (Abies balsamea (L.) Mill.) and jack pine (Pinus banksiana Lamb.). These are: total number of trees, number of trees 4 inches and up, and basal area per acre. The significance of these relationships for the stand development, and the feasibility of using height- and diameter-based indices as measures of growing stock in studies of yield are discussed.

Vézina, P.E. 1964. Derivation of thinning regimes through use of a model for balsam fir in Quebec. For. Chron. 40: 362-377.

A thinning regime was derived through use of a model developed to grow balsam fir (Abies balsamea (L.) Mill.) trees at any desired size between the limits set by normal and open stand densities. Interpolations were made between the normal number of trees in fully stocked even-aged balsam fir stands and the number at which crowns of fully open-grown individual trees just close at square spacing. The increase in the number of trees in a fully stocked balsam fir stand of a given average dbh being little influenced by site was a precommercial and two commercial thinnings, and a regeneration cutting when the stand reaches about 7 inches in dbh.

Vézina, P.E. 1963. More about the crown competition factor. For. Chron. 39(3): 313-317.

The relationship between crown width and tree diameter is presented for open-grown pine in Quebec so that "Maximum Crown Area" in square feet can be estimated from tree diameter. The relationship between maximum crown area and tree diameter provides a basis for computing the "Crown Competition Factor" (an expression of stand density) value of a stand as a measure of stand density. The CCF values for plots covering a range of ages were investigated.

Vézina, P.E. 1963. Objective measures of thinning grades and methods. For. Chron. 39(3): 290-300.

New expressions of grades and methods of thinning have recently been developed in Germany, Great Britain, the Netherlands, Norway, U.S.A., and Canada. These are described and discussed in the light of the conditions which are most commonly encountered in Canada's undisturbed forests. It was concluded that none of these indices should be used alone in any experiment, but several of them should rather be tried on a comparative basis. Continued research should eventually lead to improved methods of measuring density and structure of stands. It may also provide a better understanding of the relationships among various stand parameters.

Vézina, P.E. and Péch, G. 1964. Solar radiation beneath conifer canopies in relation to crown closure. For. Sci. 10(4): 443-451.

Observations were made in Quebec on solar radiation available daily below canopies of Abies balsamea (L.) Mill., Pinus resinosa Ait., and Pinus banksiana Lamb. during summer and winter with Bellani radiation integrators. A relationship between crown closure and the solar radiation ratio--defined as the proportion, in percent, of the amount of solar radiation available beneath canopy (in langleys), to that available in the open--was calculated for a wide range of crown closures. Variations in solar radiation in the open did not change the average ratio in the stands, but with increasing radiation in the open the scatter of values around the mean of daily solar radiation-ratios decreased. This suggested the feasibility of a short-cut method for estimating the average solar radiation ratio in coniferous stands by integrating solar radiation on a few calm and clear days. Results are discussed in relation to the radiation-intercepting properties of forest canopies, the solar radiation requirements of Abies balsamea (L.) Mill. seedlings, and silvicultural management.

Vincent, A.B. 1962. The silvics of black spruce: A literature review. For. Res. Br., Can. Dept. For., Richmond Hill, ON; Ontario; 62-17, 201 pp.

The purpose of this paper was: (1) to determine the amount and quality of information on the species that is available in publication, and government and industry files, and its usefulness in assessing the need for, and direction of, a research program in black spruce (Picea mariana (Mill.) B.S.P.) regeneration silviculture; (2) to prepare a paper on black spruce based on a detailed literature review and information collected from unpublished material; and (3) to prepare a problem analysis based on (1) and (2).

Voorhies, G. 1982. Incidence and severity of compression wood in thinned stands of young-growth ponderosa pine. North. Ariz. Univ., Sch. For., Flagstaff, AZ; Ariz. For. Note No. 15, 11 pp.

The purpose of this Forestry Note is to report the results of an exploratory study of the incidence and severity of compression wood found in young-growth ponderosa pine (Pinus ponderosa Laws.) trees, 7-12 inches dbh, that had been thinned at different times over the past 24 years. The discussion and data presented for this exploratory study indicates an incidence of moderate to severe compression wood in thinned young-growth ponderosa pine of about 16 percent. However in 43 percent of the affected trees compression wood did not extend beyond the sixth ring from release and none beyond the 16th ring. A progressive decrease in compression wood from the base of the tree to a height of 20 feet is indicated.

Walker, L.C. 1968. Tenth annual compilation of forest fertilization and nutrition reports. Compilation of reviews by forestry consultant. 99 pp.

Synopsis: This work contains a compilation of reports based upon forest fertilization and nutrition. Information is given on organization, location, personnel, title, objectives, description and results of various reports. Included is a section of abstracts for articles on the topic presented.

Wambach, R.F. 1967. A silvicultural and economic appraisal of initial spacing in red pine. Ph. D. Thesis, Univ. Minnesota, 282 pp.

The purpose of this study was to search for means of achieving greater economic efficiency in the establishment and management of red pine (Pinus resinosa Ait.) plantations. The study involved basically two phases; the first was the establishment of a mensurational-silvicultural base, and the second was an economic analysis applied to this foundation. The objectives were: 1) In the mensurational-silvicultural phase, determine the effect of initial spacing on volume production, stand parameters, and tree characteristics. These relationships were to be quantified so that they could serve as production functions on which to base an economic analysis; and 2) In the economic analysis, compare spacing alternatives and determine optimum spacings for certain sets of conditions. If optimum spacings cannot be precisely defined, a narrow range of spacings will be designated to show where the economic optimum is most likely to fall.

Watt, R.F. and Heinselman, M.L. 1965. Foliar nitrogen and phosphorus level related to site quality in a northern Minnesota spruce bog. Ecology. 46(3): 357-361.

Channels of relatively rapid water movement, termed "water tracks," in black spruce (Picea mariana (Mill.) B.S.P. bogs in former glacial Lake Agassiz are often associated with a rich flora and shallow peat. Adjacent areas of lesser water movement are characterized by a depauperate, less productive flora and deeper peats. Black spruce foliage, collected from transects running from the good site in the water track with vigorous stands to the very poor muskegs bearing stunted trees one-fourth mile distant, was analyzed for 13 mineral elements. Nitrogen and phosphorus levels were significantly correlated with site quality; potassium displayed an inverse correlation. Levels of N and P were low, generally below the point at which deficiency symptoms have been reported for this or other spruces. The inverse relationship of potassium is a growth dilution effect, since the levels appear sufficient on all sites. The higher levels of nitrogen on good sites may be attributed to nitrogen fixation by speckled alder, which is abundant on the good sites but absent on poorer sites. More rapid decomposition of litter, indicated by lesser depth of peat accumulation, movement of enriched water, and nearness of mineral subsoil, may influence the level of N and P in the water track. Other elements were not related to site quality for black spruce.

Weber, M.G. and Cleve, K. van. 1984. Nitrogen transformations in feather moss and forest floor layers of interior Alaska black spruce ecosystems. Can. J. For. Res. 14: 278-290.

Permafrost-free and permafrost-dominated black spruce (Picea mariana (Mill.) B.S.P.) ecosystems in interior Alaska were treated with low addition levels of high enrichment isotope (<1% of the total nitrogen pool with 99 at.% excess $^{15}N$) to describe nitrogen dynamics through pools of selected forest floor components. A thick carpet of mosses, made up primarily of the feather moss species Hylocomium splendens (Hedw.) B.S.G. and Pleurozium schreberi (B.S.G.) Mitt. seemed to play a vital role in the nitrogen economy of the forest floor. Nitrogen, quickly immobilized in the moss layers (green, brown) and retained there, was released very slowly to the lower organic layers (021 + 022) where most of the vascular plant roots were located. $^{15}N$ uptake by the vascular understory was minimal, as was $^{15}N$ export via the soil solution. Periodic mineralization episodes, more frequent and dynamic at the permafrost-free site (where C/N ratios were lower), were largely restricted to the moss layers since available N fractions in deeper forest floor layers incorporated little label over the 3-year period. In the lower layers of the forest floor (021 + 022) temperature rather than organic matter quality appeared to be the overriding factor controlling N flow.

Weetman, G.F. 1975. Ten-year growth response of black spruce to thinning and fertilization treatments. Can. J. For. Res. 5: 302-309.

A 65-year-old upland black spruce (Picea mariana (Mill.) B.S.P.) stand near Baie Comeau, Quebec, was thinned and fertilized with urea; each treatment was at 2 levels in a split plot factorial design. The trees responded to the nitrogen addition after 1 year and to thinning after 7 years. The trees were still growing faster in response to most treatments after 10 years. Trees of all size classes responded to the treatments. The periodic increment was not increased by 25% thinning, but was increased by 50% thinning and was always increased by nitrogen additions. Absolute increases over control values ranged from 130 to 290 $ft^3$ (11 to 24.6 $m^3$) for an application of 100 lb N per acre (112 kg N per hectare) and 238 to 297 $ft^3$ (20 to 25.2 $m^3$) for 400 lb N per acre (444 kg N per hectare) (1 ha = $10^4$ $m^2$). Some synergistic effect of combined thinning and fertilizer treatments is indicated.

Mortality losses in the 10-year period were appreciable because of excessive stand density. The roles of thinning and fertilizer treatments in black spruce management are discussed.

Weetman, G.F. 1967. Growth and nutrition of black spruce planted on an upland raw humus cutover. Typewritten paper prepared for Tree Planters' Notes, 1967. 10 pp.

As part of a larger study of the nitrogen cycle in a stand of upland black spruce (Picea mariana (Mill.) B.S.P.) north of Baie Comeau, on the North Shore of the St. Lawrence River, Quebec, a portion of the 65-year-old stand was clearcut and planted with wilding trees, four- to six-years of age, collected along the side of the road. Following cutting in 1961, groups of six wilding black spruce seedlings were used to test the effects of manually mixing the humus and mineral soil, of adding 400 pounds per acre of nitrogen as urea to 8-foot-square blocks plus 2.5 ounces of superphosphate placed in bands around each tree, and of the combination of these two treatments, together with a control treatment of planting directly in the humus. In order to check the responsiveness of this site to the additions of ash elements either by simulated burning or by additions of chemical fertilizers, a separate study was conducted in the greenhouse.

Results of both field experiments and greenhouse studies indicate high nitrogen concentrations in the humus layer while high potassium concentrations were exhibited in the subsequent soil layers. It is suggested some form of scarification take place to mix the soils thus providing a nutritional balance of necessary elements.

Weetman, G.F. 1966. A soil fertility study of old field soils from the Grand'Mere plantation, Quebec: A pot trial with two soils and foliar analyses of the plots manured in 1920. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; Woodl. Res. Index No. 181, Res. Note No. 63, 26 pp.

A soil from the poorest portion of the Grand'Mere 1920 plantation and a soil from the plot manured at the time of planting, both growing white spruce (Picea glauca (Moench) Voss), were subjected to 10 different treatments in a pot trial lasting 10 months. White spruce seedlings showed sustained and significantly better growth only in treatments involving additions of organic matter, either as raw horse manure or as raw or sterilized litter from the manured plot. A significant response to a mixture of bentonite and NPK was short-lived. Foliar analyses of white spruce trees from plots which received 15 to 30 tons per acre of horse manure at the time of planting in 1920 and grew rapidly until 1952, did not show any consistent relationship between plot treatment and current foliar contents of N, Mg or Ca, but P and K levels were higher in the manured plots. The response of white spruce, growing on degraded sandy soils, to additions of litter or horse manure is discussed in terms of nutrient release. It is concluded that the most economical course to reforest such abandoned farm land would be to plant trees of lowest nutrient demand, such as pines, and then to correct any nutrient deficiencies which may develop by adding mineral fertilizers.

Weetman, G.F. and Algar, D. 1974. Jack pine nitrogen fertilization and nutrition studies: Three year results. Can. J. For. Res. 4: 381-398.

The response of a 40-year-old even-aged jack pine (Pinus banksiana Lamb.) stand to nitrogen fertilization was studied in four experiments.

Smothering of the ericaceous ground vegetation layer with straw led to increased tree growth rates and improved N uptake. The application of calcium nitrate, ammonium nitrate, and urea at 112 and 448 kg N/ha was followed by analysis of the composition of extractable humus N, together with foliar and increment analyses. After a 3-year response period, there was evidence for the superiority of the ammonium nitrate form of N fertilizer over urea. The volatilization losses, and also inadequate urease activity in the thin dry humus layer which led to delayed N uptake by the trees. Calcium nitrate, although not an efficient fertilizer, was associated with appreciable growth responses, even though increased foliar and extractable humus N concentrations were not maintained.

An optimum nutrition experiment utilizing repeated fertilization indicated that sustained foliar nutrient regimes can be maintained.

The study indicated that growth increases were associated with increased unit needle weights as well as increased foliar N concentrations. A graphical technique which analyzes treatment responses, unit needle weight, and nutrient concentration, was used to screen response data, without waiting the customary 5-year period for stem increment response.

Weetman, G.F. and Fournier, R.M. 1984. Ten-year growth and nutrition effects of a straw treatment and of repeated fertilization on jack pine. Can. J. For. Res. 14: 416-423.

Straw was added over snow to smother ground vegetation (straw experiment) in sample plots in a 45-year-old jack pine (Pinus banksiana Lamb.) stand in Quebec. Sample plots in the same stand were fertilized six times with N, P, and K in a 10-year period to maintain four foliar N regimes (optimum nutrition experiment). Smothering of ground vegetation with straw improved N nutrition and produced a sustained increase in tree growth. Sustained growth increases were obtained by repeated applications of 56 kg N/ha associated with 1.4% N foliar concentrations in current foliage. Gross volume increments of about 3 $m^3$/ha/year were sustained with these low applications. Repeated heavy N applications killed trees and reduced growth. Repeated additions of P and K with N did not produce appreciable differences in response from additions of N alone. Increment cores showed the annual development in growth as increasing over most of the 10-year period for low repeated N additions, and as increased and stable over the same period for the straw addition.

Weetman, G.F. and Fournier, R.M. 1984. Ten-year growth results of nitrogen source and interprovincial experiments on jack pine. Can. J. For. Res. 14: 424-430.

Sample plots in a 45-year-old jack pine (Pinus banksiana Lamb.) stand in Quebec were fertilized with urea, ammonium nitrate, and calcium nitrate in single applications of 112 or 448 kg N/ha. There were no significant differences in periodic volume response owing to the form of N added: applications of 112 kg N/ha gave temporary increases in stand growth which lasted 4-5 years, while applications of 448 kg N/ha produced responses lasting 7-8 years. In an experiment of the standardized interprovincial series no significant differences in periodic volume response were found although there was an indication of increased response to the addition of phosphorus (P) with nitrogen (N). Fertilizer efficiency was examined for single and repeated applications on the site. The most efficient fertilizer use was with repeated light applications of 56 kg N/ha, requiring 8 kg N for every cubic metre per hectare produced.

Weetman, G.F. and Harland, R. 1964. Foliage and wood production in unthinned black spruce in Northern Quebec. For. Sci. 10(1): 80-88.

This paper reports on an investigation of the relationship between needle weight and wood production in an undisturbed 65-year-old black spruce (Picea mariana (Mill.) B.S.P.) stand.

Weetman, G.F.; Roberge, M.R. and Meng, C.H. 1980. Black spruce: 15-year growth and microbiological responses to thinning and fertilization. Can. J. For. Res. 10: 502-509.

A 65-year-old upland black spruce (Picea mariana (Mill.) B.S.P.) stand was thinned and fertilized with urea in 1961. The 15-year total volume increases ranged from 3 to 9 $m^3$ for an application of 112 kg N/ha and from 11.5 to 12.5 $m^3$ for 448 kg N/ha. Most of the volume increases due to treatment took place in the first 10 years. Heavy thinning and fertilization had almost additive effects to produce an 86% increase in periodic gross increment. Neither periodic tree mortality nor distribution of response by tree size appeared to have been affected by treatment. Humus analyses of control plots and of plots treated with 448 kg N/ha, conducted in 1961, 1966, 1971, and 1976, indicated that after 15 years pH values were still higher, $NH_4$-N levels approached equilibrium values twice as high as controls after 10 years, leaching and volatilization losses of N were negligible, the C/N ratios were lower, and the potential for N mineralization and total biological activity were higher on the N-treated plots. Significant black spruce stand responses to N fertilization have been shown in this stand but responses have been variable in other trials with this species. Further work is needed to explain these results.

Weetman, G.F. and Webber, B. 1972. The influence of wood harvesting on the nutrient status of two spruce stands. Can. J. For. Res. 2: 351-369.

Calculations are presented on the quantities of N, P, K, Mg and Ca in the soil and above-ground portions of two spruce-pulpwood stands on sites of average fertility in northern and southern Quebec. The magnitude of the depletions of these nutrients from the site, in full-tree and tree-length methods of logging, are compared with the available and total quantities of them in the soil. The ranges of values, from the literature, for the input of these nutrients in dust and precipitation, and the losses in leaching, are presented and discussed in relation to the logging losses.

It is concluded that on both sites it is unlikely that full-tree logging will result in any reduction in growth, due to nutrient removal, during the second rotation of trees. However, nutrient depletion due to full-tree logging, particularly with respect to Ca, K and N, may require correction by means of fertilizers in forest ecosystems of marginal fertility. These are usually either dry sites with low reserves of organic matter and low exchange capacity or wet sites with excessive accumulations of organic matter. The need for further detailed studies of the nutrient cycle in different forest ecosystems is stressed. An all-aged stand of balsam fir (Abies balsamea (L.) Mill.) and red spruce (Picea rubens Sarg.) and a 65-year-old upland black spruce (Picea mariana (Mill.) B.S.P.) stand of fire origin were selected as study areas for this project.

Weihe, V.J. 1978. Assessment of optimum stand density in Norway spruce by means of the crown length ratio. Forstarchiv 49(8): 157-158. (Article in German, summary in English. Abstracted from For. Abst. 40(3):723, 1979).

It is argued that the crown length ratio, stem diameter height ratio, and normal form factor of trees of the same crown class from different stands cannot be correlated with one another, and thus used to estimate thinning intensity, because of differences in their changes with growth and in their responses to thinning. Data for Norway spruce (Picea abies (L.) Karst.) are presented to show a significant variation in form factor with site in dominant stems: values were lowest in the north (Westphalia) or at high altitude in southwest Germany.

Weihe, J. 1977. Correlation between stem diameter/height ratio, normal form factor and crown length ratio in spruce stands. Forstarchiv 48(10): 200-203. (Article in German and translated to English. Abstracted from For. Abst. 39(8): 3285, 1978).

Thinning of spruce (Picea abies (L.) Karst.) stands leads to an increase in stem diameter/height ratio and to a decrease in normal form factor. Data collected in 1959 from 5 stands 57 to 82 year old at different sites in Nordrhein-Westfalen were used to examine the simple and multiple correlations between these 3 parameters (diameter being measured at 10 % of total height) and their relationship with other stand criteria (age, height, diameter, dbh/diameter ratio, crown diameter/stem ratio, and stem taper), as well as correlations between the other criteria. The 3 parameters were too weakly correlated to permit data on one parameter to be used to make accurate estimates of the other two. It was not clear whether the correlation was influenced by location.

White, D.P. 1958. Forest research studies plant food usage. Pp. 32-37 in Forest Fertilization...A New Era. Am. Potash Inst., 57 pp.

Synopsis: This chapter discusses nursery soil fertility management, plantation fertilization, timing of fertilization, Christmas tree plantation fertilization, and, gum, seed and sap production.

Wilde, S.A.; Benson, H.P. and Mikola, P. 1951. Yield and quality of jack pine pulpwood produced on different types of sandy soils in Wisconsin. J. For. 49: 878-881.

The purpose of this study was to evaluate the capacity of different types of sandy soils for quantitative production of jack pine (Pinus banksiana Lamb.) pulpwood. The initial phase of investigation dealt with the effect of soil on the rate of stand growth. The second phase was concerned with the physical and chemical properties of wood produced on different sites; such properties to a certain degree determine the yield of usable pulp and the efficiency of the paper manufacturing process.

Wilde, S.A.; Giordano, A.; Shaw, B.H.; Fedkenheuer, A.W. and Seip, W.T. 1968. Tree spacing in forest plantations as related to soils and revenue. Univ. Wisc., Coll. Agric. Life Sci., Res. Div., Wisconsin; Bull. 589, 22 pp.

Synopsis: Plantations were examined to determine the effect of soils and ground vegetation on the growth of timber and the expected return of variously spaced stands. Jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.), and white pine (Pinus strobus L.) were included in the study.

Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G. 1965. Growth of Wisconsin coniferous plantations in relation to soils. Univ. Wisc., Agric. Exp. Stn., Madison, WI; Res. Bull. 262, 81 pp.

Synopsis: Reconnaissance surveys to determine the fate of coniferous plantations on different soils were carried out. Physiographic features, soil characteristics, and stand composition all influence productivity. Survey findings revealed the importance of soil nutrient content for growth of plantations.

Wilde, S.A.; Iyer, J.G.; Tanzer, C.; Trautmann, W.L. and Watterston, K.G. 1964. Growth of jack pine (Pinus banksiana Lamb.) plantations in relation to fertility of non-phreatic sandy soils. Soil Sci. 10(4): 162-169.

This paper reports results obtained with plantations of jack pine (Pinus banksiana Lamb.), the least-exacting native conifer, which was usually assigned to the reforestation of the poorest soils. In spite of the low requirements of this tree for moisture and nutrients, it has proved to be a highly sensitive indicator of the soil productive capacity; its growth was found to be very strongly correlated with physical and chemical soil productivity factors.

Willcocks, A.J. 1978. Growth studies on a twenty-eight year old plantation at Moonbeam, Ontario. OMNR Unpublished Report 24 pp.

The intent of this study was to provide some insight into the growth and yield of a plantation in the Northern Ontario Clay Belt, and to provide some incentive for a full scale study on stand dynamics for managed plantations in the area.
The plantation studied was a white spruce (Picea glauca (Moench) Voss) plantation located at the Bonner Tree Improvement Centre, Moonbeam, Ontario (formerly Spruce Falls Power and Paper Company Nursery).

Wilson, F.G. 1979. Thinning as an orderly discipline: A graphic spacing schedule for red pine. J. For. 77(8): 483-486.

The key correlation of stem count to height has been applied to define and to regulate the density of the residual stand after periodic thinning of a red pine (Pinus resinosa Ait.) plantation at Star Lake, Wisconsin. A chosen value of added height growth has determined the length of each thinning interval. Graphic evaluation of data from European yield tables for Scotch pine (Pinus sylvestris L.) has served to guard against discordant treatment.

Wilson, F.G. 1955. Evaluation of three thinnings at Star Lake. For. Sci. 1(3): 227-231.

Synopsis: Three thinnings were performed in a red pine plantation (Pinus resinosa Ait.) to control stand density. It was found that basal area, height and dbh of the red pine stand exceeded that of a residual Scotch pine stand after accretion thinning. It is also suggested commercial thinnings could prove profitable.

Wilson, G.M. 1952. Thinning jack pine Nisbet Forest Reserve, Saskatchewan. Can. Dept. Resour. Dev., For. Br., For. Res. Div., Ottawa, ON; Silv. Res. Note No. 99, 24 pp.

The purpose of the experiment was to determine the effect of different intensities of thinning on diameter, height, and volume growth of a young jack pine (Pinus banksiana Lamb.) stand.

Wilson, G.M. 1951. Thinning 30 year old jack pine. Dept. Res. Dev., For. Br., Ottawa, ON; Silv. Leafl. No. 52, 3 pp. (Project MS-18).

In 1924 on the Nisbet Provincial Forest, Saskatchewan, an experiment was established to test three different degrees of thinning in a 30 year old stand of jack pine (Pinus banksiana Lamb.) averaging 2.6 inches in diameter and containing 2,300 trees per acre. It is concluded that none of the treatments given this stand of jack pine resulted in any worthwhile improvement in the growth of the stand.

Winston, D.A. 1977. Fertilization and strip thinning in 45-year-old jack pine in Ontario. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-256, 9 pp.

Fertilization with nitrogen and phosphorous was carried out on a 45-year-old jack pine (Pinus banksiana Lamb.) stand in which a commercial strip-thinning operation had been conducted the previous year. The same fertilizer treatments were carried out on portions of an adjacent unthinned control stand.

Despite a 40% reduction in growing stock, trees in the thinned portion produced as much total volume increment as did the unthinned control over a 4-year period. A fertilizer treatment of N 168 kg/ha plus P 112 kg/ha on the thinned stand produced 5 $m^3$/ha and 7.5 $m^3$/ha more wood (total volume) than did the thinned and unthinned controls, respectively.

In the unthinned portion of the stand, total volume increment increased with increasing fertilizer N to the N 336 P 112 kg/ha level, which produced 17 $m^3$/ha over the control.

It is suggested that strip thinning and fertilization deserve greater consideration in jack pine silviculture.

Winston, D.A.; Morrison, I.K. and Foster, N.W. 1977. Height and diameter growth response of 10-year-old jack pine to thinning and fertilization. Bi-M. Res. Notes 33: 34-36.

In 1971 an experiment was established to determine the effect of thinning and fertilization, alone and in combination, on the growth, survival, and development of 10-year-old jack pine (Pinus banksiana Lamb.) in northeastern Ontario. The following is a report on the results obtained after four growing seasons.

Winston, D.A.; Morrison, I.K. and Foster, N.W. 1977. Nitrogen and herbicide treatments in semimature jack pine forest, Chapleau, Ontario: Fifth-year results. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Rep. O-X-266, 12 pp.

In May 1970, a 3 x 4 factorial experiment, replicated three times, was established to determine the effects of killing ground vegetation by herbicides, in combination with nitrogen fertilization, on the growth of 45-year-old jack pine (Pinus banksiana Lamb.). Two herbicides, singly and in combination, paraquat and simazine were applied to ground vegetation in 0.8 ha square plots. Nitrogen fertilizer treatments using urea at 0, 168, and 336 kg N/ha were applied. After 5 years the response variables, mean DBH increment, BA increment, percent BA growth, total volume increment, and merchantable volume increment were estimated. Herbicide was associated with increased growth of jack pine in only one instance: a combination of paraquat and simazine increased mean DBH increment. Nutrient tie-up by ground vegetation does not appear to be an important limiting factor in jack pine tree nutrition.

Wood, J.E. and Dominy, S.W.J. 1985. Black spruce, white spruce, and jack pine outplantings in boreal Ontario: Bare-root vs. paperpot stock and spring vs. summer planting. Great Lakes For. Res. Cent., Can. For. Serv., Sault Ste. Marie, ON; Inf. Rep. O-X-368, 67 pp.

This report presents five-year results of a study to evaluate the comparative field performance of spring- and summer-planted Japanese paperpot, transplant and/or seedling stock. From 1974 to 1981, 18 experimental plantations were established on a range of typical boreal forest sites in Ontario. Included in the experiments were one or more of the following species: black spruce (Picea mariana (Mill.) B.S.P.), white spruce (Picea glauca (Moench) Voss), and jack pine (Pinus banksiana Lamb.). Several trends were evident in most of the experiments. Spring-planted spruce transplants were superior to spring-planted paperpot and seedling stock. Black spruce paperpots planted in July generally had higher survival and were in better condition than was July-planted bare-root stock. Summer-planted white spruce paperpot and rising transplant stock demonstrated equivalent performance. The spring-planted jack pine paperpots frequently achieved survival and growth rates similar to those of spring-planted seedlings and substantially higher than those of July-planted rising seedlings. It appears that paperpot stock of the three species examined may be planted until the end of July provided that good care is taken of stock during transportation and handling.

Woodhead, P.V. 1934. Thinning lodgepole pine stands in the central Rocky Mountain region. J. For. 32: 594-597.

Synopsis: Lodgepole pine (Pinus contorta Dougl.) thinnings are restricted very largely to single-storied, densely-stocked stands of second growth, which are the result of natural reseeding on burned-over areas. Specifications for thinning, basis for spacing specifications, slash disposal methods, and mechanics of thinning are described in this paper.

Woods, M.E. and Beckwith, A.F. 1987. Storability of black spruce in the clay belt. OMNR, Toronto, ON; 15 pp.

This study provides a method by which the life and yield expectancy of mature and overmature black spruce (Picea mariana (Mill.) B.S.P.) stands can be predicted. It differs from the normal yield table approach by reflecting the loss of volume caused by severe windstorms and presents a set of empirical yield tables. The presented empirical yield tables provide realistic volume estimates, showing that more rapidly growing stands (better site classes) attain maximum growth earlier and therefore, have shorter biological rotation ages than the poorer site classes. While Site Classes IA, I and II reach maximum volume yield at definite ages and a common height range before sudden declines in volume, Site Class III volumes decline much more slowly and provide the opportunity for holding the growing stock for a much greater time on the stump.

Yang, K.C. 1987. Effects of forest practice on wood quality. Pp. 113-117 in Galloway, R.L.; Greet, R.M.; McGowan, D.W.J. and Walker, J.D., eds. Primeval Improvement: The New Forestry Age. Great Lakes For. Cent., Can. For. Serv., Sault Ste. Marie, ON; (COJFRC Symposium Proceedings O-P-15).

A list of various silvicultural treatments such as spacing, thinning, fertilization, irrigation, pruning and rotation altering wood quality is presented. Specific gravity and fibre morphology impacts on pulping, paper making and paper properties are listed. The requirements of wood properties for various end uses are different from product to product. It may be useful to specify the end use of each plantation in a forest management plan so plantations can be managed accordingly.

Yang, K.C. 1987. Wood properties, wood qualities and silvicultural treatments. Q. J. Chin. For. 20(2): 7-28.

Variation of six wood properties, viz., specific gravity, fibre length, growth ring, latewood percentage, juvenile wood and sapwood/heartwood percentage are reviewed and discussed. The impact of wood properties on finished wood products is discussed and presented in tables. Influence of silvicultural treatments, i.e., spacing, thinning, fertilization, irrigation, pruning and rotation on wood properties are discussed in detail.

Yang, K.C. and Hazenberg, G. 1987. Geographical variation in wood properties of Larix laricina juvenile wood in northern Ontario. Can. J. For. Res. 17(7): 648-653.

Growth rate, latewood ratio, specific gravity, and tracheid length of Larix laricina (Du Roi) K. Koch juvenile wood were studied with two 12-mm increment cores extracted at breast height from 240 healthy trees from 12 locations at a range in latitude from 46 to 56° N in northern Ontario. Ten trees were selected from each stand and two stands were chosen from each location. Univariate analyses of variance indicated that growth rate and latewood of juvenile wood varied significantly in various locations, stands and trees at the $\delta = 0.01$ level of significance. Growth rate of juvenile wood decreased from a lower latitude to a higher latitude, whereas latewood ratios displayed a reverse trend, i.e., a higher latewood ratio was found at a higher latitude. Specific gravity of juvenile wood varied significantly in individual trees. Tracheid length varied significantly among locations, stands, and trees. The overall average growth rate, tracheid length, and specific gravity are 1.29 mm per ring, 2.10 mm and 0.43 respectively. An unexpected relationship was found between growth rate and tracheid length. Growth rate of juvenile wood has a positive relationship with tracheid length and an inverse relationship with specific gravity.

Yang, R.C. 1986. Growth of 25-year-old lodgepole pine after juvenile spacing in western Alberta. North. For. Res. Cent., Can. For. Serv., Edmonton, AB; For. Manage. Note No. 38, 8 pp.

A study was initiated in 1967 to monitor lodgepole pine stand development at various spacings to derive spacing and thinning guidelines. Ten-year results of the study have been reported by Johnstone (1982). This Note presents results to 15 years after treatment and gives some tentative guidelines for managing lodgepole pine (Pinus contorta Dougl. var latifolia Engelm.) in western Alberta.

York, E.T. 1958. Are forest trees really different. Pp. 48-53 in Forest Fertilization...A New Era. Am. Potash. Inst., 57 pp.

Synopsis: This chapter relates trees and their nutrient requirements to use of fertilizers with agricultural crops.

Zahner, R. and Oliver, W.W. 1962. The influence of thinning and pruning on the date of summerwood initiation in red and jack pines. For. Sci. 8(1): 51-56.

The influence of thinning and pruning, on the initiation of small-diameter, summerwood-like tracheids was studied in young red pine (Pinus resinosa Ait.) and jack pine (Pinus banksiana Lamb.) in southern Michigan. The dates of changeover from large to small diameter cells were established at two stem positions - at the base of the live crown, and at breast height - by comparing photomicrographs of new xylem tissue sampled weekly throughout the summer of 1959. Cell size change-over is discussed with respect to thinning and pruning.

Zavitkovski, J. and Dawson, D.H. 1978. Structure and biomass production of 1- to 7-year-old intensively cultured jack pine plantation in Wisconsin. North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, MN; Res. Pap. NC-157, 15 pp.

Spacing and rotation length effects were studied for 7 years in intensively cultured jack pine (Pinus banksiana Lamb.) stands. Production culminated at age 5 in the densest planting and progressively later in more open spacing. Biomass production was two to several times higher than in jack pine plantations grown under traditional silvicultural systems.

Zehngraff, P. and Zasada, Z.A. 1949. When does a red pine reach highest value. Lake States For. Exp. Stn., USDA For. Serv., St. Paul, MN; Tech. Notes No. 311, 2 pp.

The curves on the chart, which are the result of several tree development and utilization studies in northern Minnesota, show the value of a well developed red pine (Pinus resinosa Ait.) tree at different ages and diameters. The chart emphasizes that a stand of trees should be managed and utilized for quality production. Forest management should strive to develop as many high-quality trees as possible, since these are the profit makers for the owner. The profit trees do no reach their highest value until quite late in life.

Zeide, B. 1978. Standardization of growth curves. J. For. 76(5): 289-292.

It is shown that precisely two points are necessary and sufficient to determine any stand growth curve. Accordingly, the diversity in growth curves of forests throughout the world is reduced to a few types that accurately describe growth of any coniferous or hardwood high forest stand.

Zobel, B. 1981. Wood quality from fast-grown plantations. Tappi 64(1): 71-74.

As forestry becomes more intensive and as forestry operations move toward the tropical areas, an increasing proportion of the wood available to the industry will come from young, fast-grown plantations. The wood of such trees, especially from the conifers, is so different that it will have a major effect on utilization and product standards. Acceptability of wood from fast-grown plantations will change as solid wood and paper quality standards change. Some of the primary effects on wood and products from fast-grown plantations are discussed in this paper. The wood is very suitable for some products and poor for others. The paper reports on conifers and hardwoods separately, with a large section on Eucalyptus.

Zobel, B.J. 1970. Industrial tree improvement in the south. Pp. 3-26 in Besley, L. and Balloch, E.A., Chairman. Proceedings of the Seminar on Forest Genetics and Forest Fertilization. Pulp Pap. Res. Inst. Can., Pointe Claire, QU; 81 pp.

Synopsis: This section of the paper covers the minutes of Dr. Zobel's presentation. Topics presented were improved yields and shortage of wood. Description of slides presented are also given along with the discussion following the presentation.

# APPENDICES

## List of Forest Tree Species

| Scientific Name (Authority) | Common Name | Abbrev. |
|---|---|---|
| Abies balsamea (L.) Mill. | Balsam fir | BF |
| Abies concolour (Gord. & Glend.) Lindl. | White fir | WF |
| Abies pectinata | European fir | EF |
| Abies procura Rehd. | Noble fir | NF |
| Abies spp. | Fir species | STW |
| Acer pensylvanicum L. | Striped maple | STM |
| Acer rubrum L. | Red maple | RM |
| Acer saccharum Marsh. | Sugar maple | SM |
| Alnus rubra Bong. | Red alder | RAL |
| Betula alleghaniensis Britton. | Yellow birch | BY |
| Betula papyrifera Marsh. | Paper birch | BW |
| Betula populifolia Marsh. | Gray birch | BG |
| Fagus grandifolia Ehrh. | American beech | BE |
| Fagus sylvatica L. | European beech | EBE |
| Fraxinus americana L. | White ash | AW |
| Fraxinus nigra Marsh. | Black ash | AB |
| Larix decidua Mill. | European larch | ELA |
| Larix eurolepis Henry | Dunkeld larch | DLA |
| Larix laricina (Du Roi) K. Koch | Eastern larch (tamarack) | LA |
| Larix leptolepis (Sieb. & Zucc.) Gord. | Japanese larch | JLA |
| Picea abies (L.) Karst. | Norway spruce | NS |
| Picea glauca (Moench) Voss | White spruce | SW |
| Picea mariana (Mill.) B.S.P. | Black spruce | SB |
| Picea rubens Sarg. | Red spruce | SR |
| Picea sitchensis (Bong.) Carr. | Sitka spruce | SS |
| Picea spp. | Spruce species | STW |
| Pinus banksiana Lamb. | Jack pine | PJ |
| Pinus contorta Dougl. | Lodgepole pine (shore pine) | LPP |
| Pinus contorta var. latifolia Engelm. | Lodgepole pine (mountain form) | MLPP |
| Pinus elliottii Engelm. | Slash pine | PSL |
| Pinus jeffreyi Grev. & Balf. | Jeffrey pine | PJE |
| Pinus monticola Dougl. | Western white pine | PWW |
| Pinus nigra Arnold | Austrian pine | PA |
| Pinus nigra var. maritima (Ait.) Melv. | Corsican pine | PAM |
| Pinus palustris Mill. | Longleaf pine | PL |
| Pinus pinaster Ait. | | PPI |
| Pinus ponderosa Laws. | Ponderosa pine | PP |
| Pinus radiata D. Don | Monterey pine | PM |
| Pinus resinosa Ait. | Red pine | PR |
| Pinus strobus L. | White pine | PW |

| Scientific Name (Authority) | Common Name | Abbrev. |
|---|---|---|
| Pinus sylvestris L. | Scotch, Scots pine | PS |
| Pinus taeda L. | Loblolly pine | LBLP |
| Pinus spp. | Pine species | STW |
| Populus grandidentata Michx. | Bigtooth, Largetooth aspen | LTA |
| Populus tremuloides Michx. | Quaking aspen | TA |
| Populus spp. | Poplar species | HW |
| Prunus pensylvanica L.f. | Pin cherry | PCH |
| Pseudotsuga menziesii (Mirb.) Franco. | Dougla fir | DF |
| Salix spp. | Willow species | HW |
| Thuga occidentalis L. | Northern White-cedar | NCE |
| Thuga plicata Donn | Western Redcedar | RCE |
| Tsuga canadensis (L.) Carr. | Eastern Hemlock | HE |
| Tsuga heterophylla (Raf.) Sarg. | Western Hemlock | WHE |
| | Softwoods | STW |
| | Hardwoods | HW |
| | Non-specific | NON |
| | Mixedwoods | MW |
| | Spruce-Fir | S-F |

## Pathological/Entomological Terms

| Scientific Name (Authority) | Common Name |
|---|---|
| Arceuthobium americanum Nutt. | Lodgepole pine dwarf mistletoe |
| Armillaria mellea (Vahl.) Quel. | Shoestring root rot |
| Atropellis piniphila (Weir) Lohman & Cash | Atropellis canker of pines |
| Coleosporium asterum (Diet.) Syd. | Pine needle rusts |
| Cronartium comandrae Pk. | Comandra blister rust |
| Cronartium comptoniae Arth. | Sweetfern blister rust |
| Cronartium coleosporioides Arth. | Stalactiform blister rust |
| Cronartium quercuum (Berk.) Miyabe | Eastern gall rust |
| Endocronartium harknessii (J.P. Moore) Y. Hiratsuta | Western gall rust |
| Fomes annosus (Fr.) Cke. | Fomes root and butt rot |
| Hylocomium splendens (Hedw.) B.S.G. | Feather moss species |
| Hypodermella ampla (Davis) Dearn. | Jack pine needle cast |
| Peridermium harknessii Moore | Western gall rust (jack pine, ponderosa pine, Jeffrey pine, Lodgepole pine) |
| Petrova comstockiana (Fernald) (Petrova spp.) | Pitch twig moth |
| Pissodes terminalis Hopp. | Pine weevil (Lodgepole pine) |
| Pleurozium schreiberi (B.S.G.) Mitt. | Feather moss species |
| Polyporous tomentosus Fr. | False velvet top fungus |

## Machine-Readable Cataloging (MARC) Library of Congress Publication Code for Provinces, States, & Countries

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| Africa | AF |
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| Florida | FL |
| Georgia | GA |
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| Missouri | MO |
| Montana | MT |
| Nebraska | NB |
| Netherlands | NLD |
| Nevada | NV |
| New Brunswick | NK |
| New Foundland | NF |
| New Hampshire | NH |
| New York | NY |
| North Carolina | NC |
| North Dakota | ND |
| Nova Scotia | NS |
| Ohio | OH |
| Ontario | ON |
| Oregon | OR |
| Pennsylvania | PA |
| Prince Edward Is. | PI |
| Quebec | QU |
| Romania | RO |
| Saskatchewan | SN |
| South Carolina | SC |
| Sweden | SW |
| Tennessee | TN |
| Texas | TX |
| Utah | UT |
| Vermont | VT |
| Virginia | VA |
| Washington | WA |
| Wisconsin | WI |
| Wyoming | WY |

## Metric (SI and Derived) Units and Their ( nadian Yard/Pound Equivalents

| SI Units | | Yard/Pound Equivalents |
|---|---|---|
| **Length** | | |
| 1 mm (millimetre) | = | 0.039 370 1 inch |
| 1 cm (centimetre) | = | 0.393 701 inch |
| 1 m (metre) | = | 39.370 1 inches |
| 1 m (metre) | = | 3.280 84 feet |
| 1 m (metre) | = | 1.093 61 yards |
| 1 m (metre) | = | 0.049 709 7 chain (of 22 yard) |
| 1 km (kilometre) | = | 0.621 371 mile |
| **Area** | | |
| 1 $cm^2$ (square centimetre) | = | 0.155 000 square inch |
| 1 $m^2$ (square metre) | = | 10.763 9 square feet |
| 1 $m^2$ (square metre) | = | 1.195 99 square feet |
| 1 $m^2$ (square metre) | = | 0.247 105 mil-acre |
| 1 ha (hectare) | = | 2.471 05 acres |
| 1 $km^2$ (square kilometre) | = | 0.386 102 square mile |
| **Volume Solid** | | |
| 1 $mm^3$ (cubic millimetre) | = | 1.000 061 023 7 cubic inch |
| 1 $cm^3$ (cubic centimetre) | = | 0.061 023 7 cubic inch |
| 1 $m^3$ (cubic metre) | = | 35.314 7 cubic feet |
| 1 $m^3$ (cubic metre) | = | 1.307 95 cubic yards |
| 1 $m^3$ (cubic metre) solid | = | 0.353 147 cunit (1 cunit = 100 $ft^3$ of wood) |
| 1 $m^3$ (stacked cubic metre) | = | 0.275 896 cord (1 cord = 128 stacked $ft^3$ of wood) |
| 1 hectolitre | = | 2.749 694 bushels |

| SI units | | Yard/Pound Equivalents |
|---|---|---|
| | **Volume Liquid** | |
| 1 ml (millilitre) | = | 0.035 195 1 fluid ounce |
| 1 l (litre) | = | 0.219 969 gallon |
| | **Mass or Weight** | |
| 1 g (gram) | = | 0.035 274 0 ounce (avoirdupois) |
| 1 kg (kilogram) | = | 2.204 62 pounds (avoirdupois) |
| 1 t*** (tonne) (***1 L = 1 000 kg) | = | 2 204.62 pounds |
| 1 t (tonne) | = | 1.102 31 short tons of 2000 pounds |
| | **Miscellaneous** | |
| 1°C (degree Celsius) | = | 32+1.8 (°C) degrees Fahrenheit |
| 1 J (joule) | = | 1 watt-second (exactly 0.145 038 pound-force per square inch) |
| 1 kPa (kilopascal) | = | 0.145 038 pound-force per square inch |
| 1 MPa (magapascale) | = | 145.038 pounds-force per square inch |
| 1 N (Newton) | = | 0.224 809 pound-force |
| 1 W (Watt) | = | 0.001 340 48 electric horsepower |
| 1 Pa.s (pascal-second) | = | 0.020 885 4 pound-force second per square foot |
| 1 N.m (newton-metre) | = | 8.850 75 pound-force inches |

| SI units | Ratios | Yard/Pound Equivalents |
|---|---|---|
| 1 $m^2$/ha (square metre per hectare) | = | 4.356 00 square feet per acre |
| 1 $m^3$/ha (cubic metre per hectare) | = | 14.291 3 cubic feet per acre |
| 1 $m^3$/ha (stacked cubic metre per hectare) | = | 0.111 651 cord per acre |
| 1 kg/m (kilogram per metre) | = | 0.671 969 pound per foot |
| 1 kg/$m^2$ (kilogram per square metre) | = | 0.204 816 pound per square foot |
| 1 kg/ha (kilogram per hectare) | = | 0.892 101 pounds per acre |
| 1 t/ha (tonne per hectare) | = | 0.446 090 ton (of 2 000 lb) per acre |
| 1 kg/$m^3$ (kilogram per cubic metre) | = | 0.062 428 0 pound per cubic foot |
| 1 hectolitre/hectare | = | 1.112 762 bushels/acre |
| 1 m/s (metre per second) | = | 3.280 84 feet per second |
| 1 km/h (kilometre per hour) | = | 0.621 371 mile per hour |
| 1 km/l (kilometre per litre) | = | 2.824 81 miles per gallon |
| 1 N/m (newton per metre) | = | 0.068 521 8 pound-force per foot |

## Concentrations Used in Soil and Fertilizer Prescriptions

| SI units | | Concentration |
|---|---|---|
| **Soil Analysis** | | |
| 1 mg/100 g (milligrams per 100 grams) | = | 1 part per 100 000 |
| 0.1 mg/100 | = | 1 ppm (part per million) |
| **SI units** | | **Concentration in plough layer** |
| **Fertilizer and Herbicide Prescriptions** | | |
| 1 kg/ha* (kilogram per hectare) | = | 0.446 428 57 ppm (parts per million) |
| 2.24 kg/ha | = | 1 ppm |
| 1 kg/ha | = | 0.1 $g/m^2$ |
| **Yard/pound units** | | **Concentration in plough layer** |
| 1 lb/ac** (pound per acre) | = | 0.5 ppm (exactly) |
| 2 lb/ac** | = | 1.0 ppm |
| 1 lb/ac | = | 1.120 849 kg/ha |
| 1 gal/ac | = | 11.233 623 l/ha (litres per hectare) |

*Based on 2 240 000 kg/ha ($2.24 \times 10^6$ kg/ha) plough layer 18 cm depth x 1 ha (10 000 $m^2$) with a bulk density of 1.3 $g/km^3$ (actual weight = 2 340 000 kg/ha).

**Based on 2 000 000 lb/ac ($2.0 \times 10^6$ lb/ac) plough layer 7 in. depth x 1 ac (43 560 $ft^2$) with a bulk density of 1.3 $g/cm^3$ (actual weight 2 062 179 lb/ac).

## Miscellaneous Technical Abbreviations

| Abbreviation | | Unit of Measure |
|---|---|---|
| ac. | = | acre(s) |
| cm | = | centimetre(s) |
| cd. | = | cord(s) |
| dm | = | decimetre(s) |
| ft. | = | foot(feet) |
| g | = | gram(s) |
| ha | = | hectare(s) |
| in. | = | inch(es) |
| kg | = | kilogram(s) |
| km | = | kilometre(s) |
| lb. | = | pound(s) |
| m | = | metre(s) |
| mm | = | millimetre(s) |
| ppm | = | parts per million |
| t. | = | tonne(s) |
| yr. | = | year(s) |

| Abbreviation | | Elements |
|---|---|---|
| Ca | = | calcium |
| Fe | = | iron |
| K | = | potassium |
| Mg | = | magnesium |
| Mn | = | manganese |
| N | = | nitrogen |
| P | = | phosphorus |

| Abbreviation | | Miscellaneous Terms |
|---|---|---|
| avg. | = | average |
| b.a.(BA) | = | basal area |
| bf | = | board foot(feet) |
| bh(BH) | = | breast height |
| cai(CAI) | = | current annual increment |
| CCF | = | crown competition factor |
| d(diam.) | = | diameter |
| dbh(DBH) | = | diameter at breast height |
| ht. | = | height |
| i.e.(eg.) | = | that is(example) |
| incr. | = | increment |
| mai(MAI) | = | mean annual increment |
| n.d. | = | no date |
| $R^2$ | = | co-efficient of determination |
| RD | = | relative density |
| vol. | = | volume |